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CIVIL ENGINEERING.

Railroad Cuttings and Embankments.—Side Depths and Side Stakes. By OLIVER BYRNE, C.E.

From the Lond. Civ. Eng. and Arch. Jour., Jan., 1864.

WHEN the centre stumps of a railroad have been put down, which are usually at the distance of one chain, the line must next be leveled, and the number of stumps entered in the level-book in a vertical column; and opposite each number, in another column, the depth of the cuttings or embankments; and in a third column, the horizontal half-width of the surface cuttings. But every engineer has his peculiar method of keeping a field or level-book.

To set out the width of cuttings, when the surface of the ground is laterally level, and at a given height above the level of the intended railroad, the ratio of the slopes being given, let ABDH, Fig. 1, be the cross-section of a cutting, the ground HD parallel to the bed of the road AB; put CF, the height in the centre of the road $= h$, and the breadth of the road-bed AB $= b$; the slope of the side AH or BD is generally expressed by the ratio of the base BI to the perpendicular ID; let

Fig. 1.

BI : ID $= m : n$, then the slopes are said to be $m : n$, or $\frac{m}{n}$.

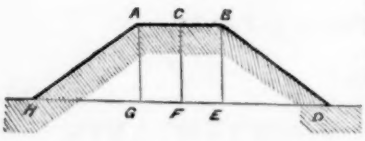
In this case, as it is supposed the ground HD is level, the distance from the centre F to the side stakes D and H will be expressed by

$$\tfrac{1}{2}b+\frac{m}{n}h.$$

Example.—Let the bottom width AB = 28 feet, the depth of the cutting CF = 16 feet, the slopes 5 : 4; that is BI : ID = 5 : 4; required the distance of the side stakes H and D from the centre F.

$$\text{HF} = \tfrac{1}{2} \text{ of } 28 + \tfrac{5}{4} \text{ of } 16 = 34 = \text{FD}.$$

Fig. 2.



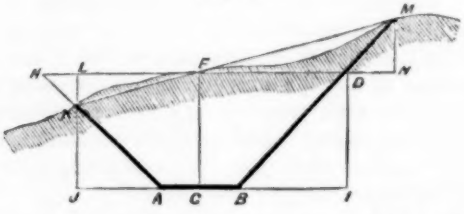
Example of embankment, when surface of the ground is laterally level (Fig. 2). Suppose the breadth of the roadway AB = 32 feet; the height of the embankment CF = 20 feet, and the ratio of the slopes 6 to 5, that is, DE : EB = 6 : 5; required the distance of the side stakes H and D from the centre F.

$$\text{HF} = \tfrac{1}{2} \text{ of } 32 + \tfrac{6}{5} \text{ of } 20 = 40 = \text{FD}.$$

The slope given to the sides of either cuttings or embankments varies with the material through which the road has to pass.

When BI = ID (Fig. 1), the slope is said to be 1 : 1. The slope is said to be a rise of 2 to 1 when IB = twice ID. In close-jointed rock the ratio varies from 1 : 4, to 1 : 2. In soft or loose-jointed rock, or stiff clay, the ratio varies from 1 : 1, to 3 : 2. If the road passes through moist springy ground or loose sand, the ratio of the slope varies from 2 : 1, to 5 : 2. Should the ground rise from F to M (Fig. 3),

Fig. 3.



the slope stake must be set out further, as at M. Let the additional height MN = p, then

DN = $\frac{m}{n}p$. And if the ground falls from F to K, a distance LK = q, the slope stake must be set further in at K, a distance HL = $\frac{m}{n}q$.

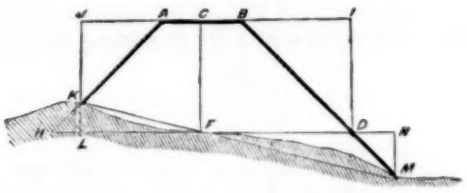
$$\therefore \text{FN} = \tfrac{1}{2}b+\frac{m}{n}h+\frac{m}{n}p$$

$$\text{FL} = \tfrac{1}{2}b+\frac{m}{n}h-\frac{m}{n}q.$$

It often happens that p and q are unequal. Setting slope stakes for

embankments resembles setting them for excavations, only a rise from the centre F with excavations, corresponds to a fall with embankments; in fact, an embankment is a cutting inverted. Fig. 4 represents an embankment, and is Fig. 3 inverted. The rise at K is nearer

Fig. 4.



the centre F, than H on the level, in an embankment (Fig. 4), while the fall at K is nearer the centre F than H on the level with F in an excavation, (Fig. 3.)

Example.—In the cutting, Fig. 3, and in the embankment, Fig. 4,

Let AB $=b=30$ feet. KL $=q=4$ feet.
CF $=h=18$ " $m : n=3 : 2$.
MN $=p=6$ "

$3 : 2=$ BI : ID $=$ AI : JK $=$ DN : NM $=$ HL : LK.

Consequently

$$\text{FN}=\frac{30}{2}+\frac{3\times 18}{2}+\frac{3\times 6}{2}=51 \text{ feet.}$$

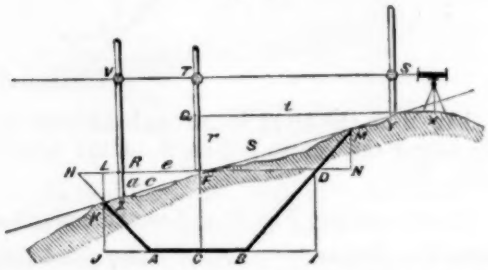
$$\text{FL}=\frac{30}{2}+\frac{3\times 18}{2}-\frac{3\times 4}{2}=36 \text{ feet.}$$

As the ground continues to slope up or down from F, the centre stake, the positions of M and K are often determined on the ground by a series of trials, or fudged out in an office by some clumsy mechanical construction or other. To avoid guessing, or rule-of thumb operations, I will lay down a practical exact plan by which the positions of the side stakes K and M may be easily found. The positions of D and H on a level with F, the centre stake, can be accurately calculated when the height CF, breadth AB, and ratio of BI to ID are given, therefore it is known, very nearly, where the lines AK and BM strike the surface of the earth. And as FK and FM are seldom in the same straight line, it is more accurate to find the ratio of FL to LK as well as the ratio of FN to NM (Fig. 5). When these ratios are known, which may be readily found by a level and target rod, the distance of M from F and of K from F are easily calculated.

In the neighborhood of M and K, there are always short spaces before or behind M and K, in the direction of the lines KF and FM, and it does not matter how irregular the surface is between these points. It is not necessary that the spaces before or behind K and M are level or not, so that they are nearly in the directions of FM and FK. Set up

and adjust the level at any convenient place X, outside the cross section; place the target-staff at Y, as near as you are able to judge, to the required point M: read off the height SY; remove the staff to the centre stake F, and read off the height FT; the difference between SY and FT will give QF, which put $=r$, measure YF, and put $s=$YF. If the distance QY be not great, it may be measured by the same tape or chain that takes the length of FY; or QY may be calculated, for QY$=\sqrt{(s^2-r^2)}$, which put$=t$ to make the reasoning more concise.

Fig. 5.



Then the three sides of the triangle QFY become known; this triangle is similar to the triangle FNM, and hence

FN : NM : : t : r
FN : FM : : t : s
FM : MN : : s : r

because the three sides of the triangle, YF, QF, QY, are respectively represented by the three known quantities, s, r, t. Two of these quantities, s and r, may be measured in links or feet on the ground, and the third side may be measured or calculated according to the circumstances of the case. Again, place the target-staff at Z as near the required point K as you are able to judge; but it does not matter where it is placed, as I have before observed, so that it is in the line FK. Then read off the height ZV without changing the position of the instrument at X; from the height ZV take TF, the remainder ZR is one of the sides of the triangle FZR; put this known height ZR$=a$; measure ZF with a tape or chain, and put it$=c$; RF may be measured and put $=e$, or calculated, for $e=\sqrt{(c^2-a^2)}$. As on the other side of the centre F, the triangle FRZ is similar to the triangle FLK.

Hence FK : KL : LF$=c$: a : e.

To render this method of proceeding as clear as possible, I have dwelt on every point of the process, so that there could be no misunderstanding. This subject has been treated by writers in a most slovenly manner; and by most of the empirical rules laid down by them, it takes three or four trials to determine the position of a side stake.

Let KF$=x$ and FM $=y$.

AB$=b$; FC $=h$; BI : ID $=m$: n.

And as we have just found by the level and target-staff that

$$\text{FN} : \text{NM} = t : r,$$
$$\text{FM} : \text{FN} = s : t;$$

Also,

$$\text{FL} : \text{LK} = e : a,$$
$$\text{FK} : \text{KL} = c : a.$$

I have selected these measures in the most general manner, in order that the result may embrace all like cases.

$$\text{C} : a :: x : \frac{ax}{c} = \text{KL}.$$

$$\text{KL} : \text{LH} = \text{KJ} : \text{JA} = n : m;$$

$$\therefore \frac{ax}{c} : \text{LH} :: n : m; \text{ or } \frac{amx}{cn} = \text{LH}.$$

$$\text{FH} - \text{HL} = \text{LF}.$$

$$\text{FH} = \tfrac{1}{2}b + \frac{mh}{n};$$

$$\therefore \text{LF} = \tfrac{1}{2}b + \frac{m}{n}h - \frac{amx}{cn}$$

$$c : e :: x : \frac{ex}{c} = \text{FL}$$

$$\therefore \frac{ex}{c} = \frac{b}{2} + \frac{mh}{n} - \frac{amx}{cn}$$

$$\therefore x = \frac{c(nb+2mh)}{2(en+am)}$$

and hence the exact distance of the side stake K from the centre F becomes known.

$$s : r :: y : \frac{ry}{s} = \text{MN}.$$

$$\text{BI} : \text{ID} = \text{DN} : \text{NM} = m : n,$$

$$\therefore n : m :: \frac{ry}{s} : \frac{mry}{ns} = \text{DN}.$$

$$\text{FD} + \text{DN} = \text{FN}.$$

$$\text{FD} = \tfrac{1}{2}b + \frac{mh}{n};$$

$$\therefore \text{FN} = \frac{b}{2} + \frac{mh}{n} + \frac{mry}{ns}; \text{ but,}$$

$$s : t :: y : \frac{ty}{s} = \text{FN};$$

$$\therefore \frac{ty}{s} = \frac{b}{2} + \frac{mh}{n} + \frac{mry}{ns}$$

$$y = \frac{s(nb+2mh)}{2(nt-mr)};$$

and hence the exact distance of the side stake M is readily determined.

Example.—Given the breadth of the roadway AB = 28 feet; the height of the centre stake CF = h = 24 feet; the ratio of the slopes AH, BM, or BI : ID = 3 : 2. In a surface distance FY = 60 feet = s. A rise FQ = 7 feet = r, is found by the level and target staff; in the surface distance, FZ = 50 feet = c, a fall RZ = 4 feet = a is found. Required the points KM where the surface of the ground intersects the slopes that form the road. The solution of this problem and of this first example are given at full length, in order that the ground-work of the practical rule, to be given presently, may be well understood.

$$FM : FN : MN = s : \surd(s^2 - r^2) : r,$$
$$FK : FL : LK = c : \surd(c^2 - a^2) : a.$$

$$60^2 = 3600$$
$$7^2 = 49$$
$$t = \surd(s^2 - r^2) = \surd 3551 = 59{\cdot}59$$
$$50^2 = 2500$$
$$4^2 = 16$$
$$e = \surd(c^2 - a^2) = \surd 2484 = 49{\cdot}84$$

$$x = \frac{50(2\times 28 + 2\times 3\times 24)}{2(49{\cdot}84\times 2 + 4\times 3)} = \frac{10000}{223{\cdot}36} = 44{\cdot}8 \text{ feet.}$$

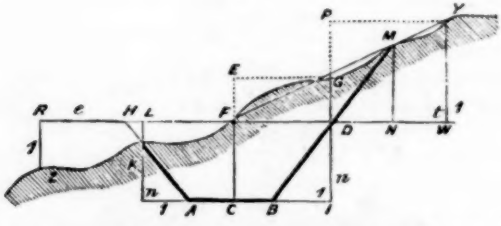
= the distance from F to K.

$$y = \frac{60(2\times 28 + 2\times 3\times 24)}{2(59{\cdot}59\times 2 - 7\times 3)} = \frac{12000}{196{\cdot}36} = 61{\cdot}11$$

the distance from F to M. Although this calculation is simple and extremely accurate, yet the generality of practical men require rules that can be applied without entering into the reasoning of the matter in every particular case and example. To suit this class of practitioners I will lay down one or two other methods of finding the values of x and y.

In Fig. 6, by the use of the level and target-staff, as described in Fig. 5, let the rise from the centre stake F, in the direction FY, be determined; which represent by the ratio t : 1. That is, FW : WY : t : 1.

Fig. 6.



In the same manner, by placing the target-staff at Z, in the neighborhood of K, find the fall from the centre stake F, so that F, Z, K, may

be in the same straight line, or nearly equal so; in general terms this ratio may be represented by e to 1, that is,

$$\text{FR} : \text{RZ} :: e : 1.$$

Before going on the ground to set out side stakes, the lines of the figure HABD are known; the horizontal half breadths FD, FH, are found from the height FC, and the breadth of the roadway AB, being given. When the positions of H and D are known, it is not difficult to select some points, Z and Y, near them to ascertain the slope of the ground. In finding the half breadth FD and FH, the ratio of BI to ID is also given; this ratio may be represented by $1 : n$, that is

$$\text{BI} : \text{ID} = 1 : n\,; \quad \text{DN} : \text{NM} = 1 : n;$$

$$\text{HL} : \text{LK} = 1 : n;$$

Put $v = \text{HL}$, then $1 : n :: v : nv = \text{LK}$.

Put $\text{HF} = d = \text{FD}$, the half horizontal breadth, through the centre stake F.

$$e : 1 :: d - v : \frac{d-v}{e} = \text{KL}; \quad \therefore \; nv = \frac{d-v}{e} \text{ and } v = \frac{d}{ne+1}.$$

Again, put $\text{DN} = z$, then

$$1 : n :: z : nz = \text{MN};$$

$$\text{and } t : 1 :: d+z : \frac{d+z}{t} = \text{MN}.$$

$$\therefore \; nz = \frac{d+z}{t}, \text{ and } z = \frac{d}{nt-1}.$$

From which the following simple practical rule may be deduced.

RULE.—When the ground rises from the centre, increase the horizontal half breadth, divided by the half breadth by the product, (less one) of the numbers that express the ratio of the rise and the ratio of the slope, and the horizontal distance of the side stake is determined. When the ground falls from the centre, decrease the horizontal half breadth, by the half breadth divided by the product (plus one) of the numbers that express the ratio of the rise and the ratio of the slope; and the horizontal distance of the other side stake is found.

Example.—Given the breadth of a railway AB = 30 feet; the height CF = 26 feet; the side slopes 1 : 2 (BI : ID :: 1 : 2); the rise of the surface from F to Y = 1 in 20 (FW : WY :: 20 : 1). The fall from F to D = 1 in 36; required the horizontal distances FN and FL, where the surface of the ground intersects the side slopes of the railroad.

$\text{HF} = \frac{30}{2} + \frac{1}{2}\,26 = 28 = \text{FD}$, half the horizontal breadth meeting the side slopes on a level line through F. The horizontal distance FW may be measured in lengths EG, PY, when the surface is irregular.

$$2 \times 20 - 1\;39, \text{ and } \tfrac{2}{3}\tfrac{8}{9} = \cdot 72$$

$$\therefore \text{FN} = 28 \cdot 72 \text{ feet}$$

$$2 \times 36 + 1 = 73, \text{ and } \tfrac{2}{7}\tfrac{8}{3} = \cdot 38,$$

$$\therefore \; 28 - \cdot 38 = 27 \cdot 62 = \text{FL}.$$

This calculation is so plain and simple, that the positions of the side

stakes are found in a few seconds. It should be noticed that in the ratios of the slopes, and inclination of the ground, unity is taken for the base of the side slopes, but for the perpendicuiar of the rise or fall of the ground.

(To be Continued.)

For the Journal of the Franklin Institute.

Suspension and Arch Truss Bridges, according to a New System.

By S. W. Robinson, C. E., Detroit, Mich.

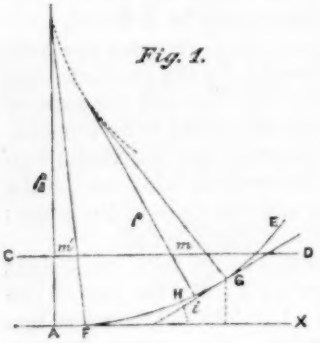
In the previous article upon "*Suspension Bridges,*" published in your last volume—which was prepared by De Volson Wood, Professor of Civil Engineering University of Michigan, from my thesis left there at the last college commencement—the tangent line to the arc at the lowest point was taken as the line of attachment of the normal suspending ties to the uniform horizontal loading. In that case the tension was found to be exactly equal to the tension at the pier heads of the ordinary form with parabolic arc.

I have since solved the problem in a more general way. I have supposed the cable to pass above, or below, the line of attachment to the loading.

A diminished tension is the result of passing the cable entirely or in part below the roadway; the span and versed sine remaining the same.

This inverted is the form for an arch truss, with a uniform and diminished stress throughout the arched chords.

Fig. 1.



Now let A E, Fig. 1, represent the arc of the cable, passing at a distance *a*, below the line C D of attachment to the loading.

Let A be the origin of co-ordinates. AF and HG equal elements of arc.

W = the weight of loading per unit of length.

WM^1 the amount to which pressure is due upon AF, and WM the amount to which pressure is due upon HG.

Then

$$M^1 = \frac{AF(\rho_o - a)}{\rho_o} \quad . \quad . \quad . \quad . \quad (A)$$

and

$$M = \frac{HG(\rho - (a - y)\sec i)}{\rho \cos i}.$$

According to theorem II of previous article

$$WM^1 \rho_o = WM \rho \sec i, \quad - \quad . \quad (1)$$

or $$AF(\rho_o - a) = \rho M \sec i = HG(\rho - (a - y)\sec i)\sec^2 i.$$

But AF was assumed equal HG.

$$\therefore \quad (\rho_o - a) = (\rho - (a-y)\sec i)\ \sec^2 i.$$

Put $u = \frac{dy}{dx}$, then $\frac{du}{dx} = \frac{d^2y}{dx^2} = \frac{udu}{dy}$ and $\rho = \frac{(1+u^2)^{\frac{3}{2}}}{\frac{udu}{dy}}$, $\sec i = \sqrt{1+u^2}$.

Hence (2) becomes by substituting and reducing,

$$(1+u^2)^{\frac{5}{2}} - (a-y)\,(1+u^2)^{\frac{3}{2}}\frac{udu}{dy} = (\rho_o - a)\frac{udu}{dy}, \qquad (3)$$

or,

$$dy + y\,\frac{udu}{1+u^2} = \left\{ \frac{a}{1+u^2} + \frac{\rho_o - a}{(1+u\ )^{\frac{5}{2}}} \right\} udu.$$

The integral of this, treated as a linear equation after correcting by determining the constant, and reducing, is,

$$y = a + \frac{\rho_o - 3a}{2(1+u^2)^{\frac{1}{2}}} - \frac{\rho_o - a}{2(\rho_o + u^2)^{\frac{3}{2}}}, \qquad (4)$$

or

$$(1+u^2)^{\frac{3}{2}} = \frac{1}{2(a-y)}\left\{ 2a - u^2\,(\rho_o - 3a) \right\}.$$

This in the second term of (3) makes it

$$dx - \frac{a\,du}{(1+u^2)^{\frac{5}{2}}} + \frac{u^2(\rho_o - 3a)du}{2(1+u^2)^{\frac{5}{2}}} = \frac{(\rho_o - a)du}{(1+u^2\ )^{\frac{5}{2}}}.$$

The integral of this is

$$x = \frac{u\rho_o}{(1+u^2\ )^{\frac{1}{2}}} - \frac{u^3\,(\rho_o - a)}{2\,(1+u^2\ )^{\frac{3}{2}}}, \qquad (5)$$

I have not attempted the complete integration of (3) as a function of x, and y, only. Much more simple expressions for the ordinates and abscissas, y and x, are obtained by introducing the variable i.

Hence, since $u = \frac{dy}{dx} = \text{tang } i$, (4) becomes

$$y = a - \cos i \left\{ a - \tfrac{1}{2}(\rho_o - a)\sin^2 i \right\}. \qquad (6)$$

And (5) becomes

$$x = \sin i \left\{ \rho_o - \tfrac{1}{2}(\rho_o - a)\sin^2 i \right\}. \qquad (7)$$

Brief discussion of the Curve.

Differentiating (6) or (7) and either gives for maximum ordinates,

$$\sin i = \pm\sqrt{\frac{2\rho_o}{3(\rho_o - a)}}, \qquad (8)$$

two equal values with contrary signs.

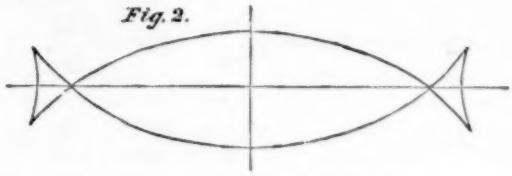
The tests for a cusp will be satisfied for both these values. Make $i=90°$. Then $\sin i=1$ $\cos i=0$. Hence,

$$y=a,\ x=\tfrac{1}{2}(\rho_o+a.)$$

For $i=180°$, $y=2a$, $x=0$.

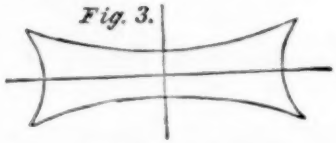
Hence, the curve is symmetrical, with respect to an axis parallel to X and at a distance a, from it. Where a is positive, the curve is as represented in Fig. 2.

Fig. 2.



When a is negative, the curve is as in Fig. 3.

Fig. 3.



Length of Arc.

$$ds=\frac{dy}{\sin i}=-\tfrac{1}{2}(\rho_o-3a)di+\tfrac{3}{2}(\rho_o-a)\cos^2 i di$$

$$\therefore\ s=\tfrac{1}{4}\left\{(\rho_o+3a)i+\tfrac{3}{2}(\rho_o-a)\sin 2i\right\}. \quad . \quad (9)$$

Length of Normal Ties.

Let $l=$ the length. Then,

$$l=(a-y)\sec i=a-\tfrac{1}{2}(\rho_o-a)\sin^2 i. \quad . \quad (10)$$

The point of attachment of the Ties to the roadway.

Let $b=$the distance from the centre to any tie. Then,

$$b=x-(a-y)\text{ tang } i=(\rho_o-a)\sin i. \quad . \quad . \quad . \quad (11)$$

Stress of the Ties.

Let P be the total stress from the origin to any point considered. Then,

$$P=wfdb\sec i,=w(\rho_o-a)i \quad . \quad . \quad (12)$$

by substituting db, from (11) and integrating.

Horizontal stress along the roadway caused by the inclined ties.

Let H=the required stress,

$$\therefore\ H=wfdb\text{ tang } i=w\int\frac{bdb}{\sqrt{(\rho_o-a)^2-b^2}}=w(\rho_o-a-\sqrt{(\rho_o-a)^2-b^2} \quad (13)$$

Tension of the Cable.

In equation (A) let AF=unity.

Then by theorem II, and equation (2) following, of my previous article

$$T=WM^1\,\rho_\circ, \text{ or } =W(\rho_\circ-a). \quad . \quad . \quad (14)$$

If in any of the preceding formulæ we make $a=0$, we get expressions identical to those of the article referred to in the last volume.

In that article the same expression was obtained for the tension of cable as in the ordinary suspension bridge at the pier heads. But when it passes below the roadway the tension is sensibly diminished.

Take the case where the line of attachment passes through the pier heads. Then this line is equal to the span. Put it=2 B.

In (10) make $l=0$.

$$\therefore \quad \sin i=\sqrt{\frac{2a}{\rho_\circ-a}}, \quad . \quad . \quad . \quad (15)$$

This in (11) gives

$$B=\sqrt{2a(\rho_\circ-a)}.$$

$$\therefore \rho^\circ=\frac{B^2}{2a}+a. \quad . \quad . \quad . \quad . \quad (16)$$

This in (14) gives

$$T=\frac{WB^2}{2a}. \quad . \quad . \quad . \quad . \quad (17)$$

That is, the tension in this case is exactly equal to the tension in the common parabolic system at the lowest point of the arc. Hence, there is a diminution of

$$\frac{WB}{2a}\left(B^2+4a^2\right)^{\frac{1}{2}}-\frac{WB^2}{2a}$$

or

$$T^1-T=\frac{WB}{2a}\left\{(B^2+4a^2)^{\frac{1}{2}}-B\right\}$$

at the pier heads.

But I believe the foregoing principles to be of more practical utility in application to *Truss Girders* with one-arched chord than to suspension bridges.

An arched chord made in parabolic arc with vertical ties and uniform loading, must increase in size from the crown to the abutments according to the formula

$$T^1=\frac{WB}{2a}(B^2+4y^2)^{\frac{1}{2}}$$

At the apex $y=o$, and

$$T^1=\frac{WB^2}{2a}.$$

But in the system with the normal ties the stress is uniform throughout and $= \frac{WB^2}{2a}$, ***the same as in the parabolic arc at the apex.***

In view of this, I have made investigation and derived formulæ necessary in the construction of arch truss girders according to the new system, which are given below.

The arched chord should not consist of portions of arc; but of the chords of those arcs between the ties and braces. And that the stress of each may be constant, the angle of any two adjacent parts should be constant, that the principle of the parallelogram of forces may be satisfied. Therefore the strain upon the ties must be the same for a uniform load throughout. Hence let it be required to find the co-ordinates of the points at which to join the ties with the arched and straight chords, that the above conditions may be fulfilled.

Equation (11) gives $\sin i = \frac{B}{\rho_o - a} = \frac{2a}{B}$:

$$\therefore \quad i = \sin.\frac{-1\,2a}{B}, \qquad . \qquad . \qquad . \qquad (18)$$

for the point of intersection of the chords.

And since the angles of intersection of the broken chord must be equal, we have for the angle of each,

$$\frac{2i}{2N+1} = i_1 \text{ and } \frac{2ni}{2N+1} = i_n = n\,i_1$$

In which $2N$ = the total number of ties.

This value of i_n and (16) in (6) and (7) give for the points in the arched chord,

$$y_n = a - \cos.\, i_n \left\{ a - \frac{B^2}{4a} \sin.^2 i_n \right\} \qquad . \qquad . \qquad (19)$$

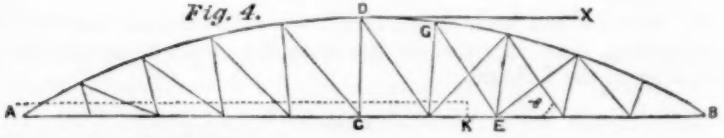
$$x_n = \sin.\, i_n \left\{ \frac{B^2}{2a} + a - \frac{B^2}{4a} \sin.^2 i \right\} \qquad . \qquad . \qquad (20)$$

From (11) for the horizontal chord we have

$$b_n = \frac{B^2}{2a} \sin.i_n .$$

Dimensions of the parts.

Fig. 4.



Let L = length of a brace

b'_n = the distance from centre to middle of bay considered,

c = length of one part of the broken chord.

$$i'_1 = \tfrac{1}{2} i_1 \quad \therefore \quad i'_n = (n - \tfrac{1}{2}) i_1$$

Other notation as before.

The length of a tie (10) is

$$l_n = a - \tfrac{1}{2}(\rho_o - a)\sin^2 i_n$$

$$= a - \frac{B^2}{4a}\sin^2 i_n \quad . \quad . \quad . \quad (21)$$

The length of any portion of the arched chord is

$$c_n = (x_n - x_{n-1})\frac{1}{\cos i'_n} \quad . \quad . \quad (22)$$

The length of a brace is

$$L_n = \left(a - y_{n-1}\right)\frac{1}{\sin \theta_n} \quad . \quad . \quad (23)$$

$$\text{for which } \operatorname{tang} \theta_n = \frac{a - y_{n-1}}{b_n - x_{n-1}}$$

Stress of the Parts.

The maximum strain upon the middle of the chord is when the bridge is loaded throughout and is given by (17). This may also be shown geometrically.

This decreases toward the extremities of the horizontal chord according to (13). Hence the strain in the n^{th} bay is

$$\frac{WB^2}{2a} - W\left(\rho_o - a - \sqrt{(\rho_o - a)^2 - b_n^2}\right) = \frac{W}{2a}\sqrt{B^4 - 4a^2 b_n^2}. \quad (24)$$

This shows that when $a = \frac{1}{2}B$ the stress of the lower chord is $= 0$ at the abutments for a uniform load. But when the load enters the bridge there is a horizontal thrust given by (26), which *may* exceed that of (24).

The maximum stress of a brace is when the load extends from the middle of the bay considered to the end toward which the brace inclines.

From the middle of bridge to middle of bay considered:

$$b'_n = \frac{B^2}{2a}\sin i'_n .$$

Let AK, Fig. 4, represent the load which causes the maximum strain upon the brace EG. Then taking moments about A, the vertical force at B is

$$V_n = \frac{W(B + b'_n)^2}{4B}. \quad . \quad . \quad (25)$$

which is communicated to G by the transverse shearing. The sign of b' changes for $n = 0$, or negative.

Similarly the horizontal thrust at G is

$$H_n = \frac{B - x_{n-1}}{a - y_{n-1}} V_n . \quad . \quad . \quad . \quad (26)$$

in which x becomes positive, when n is negative. The resultant of

these two forces, H_n and V_n, is directed at B, which can be shown geometrically, since

$$\frac{V_n}{H_n} = \frac{a - y_{n-1}}{B - x_{n-1}} = \tan EBG.$$

Hence the stress of the brace is the resultant of these two forces resolved into it.

Let v = the stress of the brace, and h = that of the chord.

$$\therefore \left.\begin{aligned} v \sin \theta_n + h \sin i' &= V \\ v \cos \theta_n + h \cos i' &= H \end{aligned}\right\}$$

From which

$$v_n = \frac{V_n - H_n \tan i'_n}{\sin \theta_n - \cos \theta_n \tan i'_n}$$

in which the negative signs become positive when n is negative.

The maximum stress of the ties *may* be produced by the pressure of the braces.

The total pressure upon half the ties for uniform load (12), is

$$P = \frac{WB^2 i}{2a} = \frac{WB^2}{2a} \sin \frac{-1\ 2a}{B}.$$

Hence the resulting strain upon one tie is $\frac{2P}{2N+1} = p$.

But the stress caused by the braces for partial load is

$$t_n = \frac{V_{n+1} - H_{n+1} \tan i'_n}{\cos i_n + \sin i_n \tan i'_n}$$ in which H is negative when n is negative.

$\therefore$ for $n = 0$ $t = \frac{WB}{4}$ nearly, which is greater than p unless 2N be less than 8 or 9, in ordinary cases.*

If it should be desired to substitute diagonal ties for the braces, expressions for the stress of the various part scould be derived similarly as the above.

It might be added that a can never exceed $\frac{1}{2}B$, for in this case the position for the cusp would be below the roadway in the suspension, and above in the arch truss bridge. Equation (8) would also become imaginary.

In the case when $a = \frac{1}{2}B$ there is no cusp for the points, for each is coincident, and in the roadway. Hence for this case the curve is continuous, and intersects its axis but once on each side of the origin.

* If B = 8, a = 2, W = 1, 7 = 2N, then i = 30°, 2P = 16·755 + $\frac{2P}{2N+1}$ = 2·09 +, and t = 1·868 +, which is less than p: but if 2N = 10, t will be greater than p.

For the Journal of the Franklin Institute.

Omissions in a Closed Survey. By De Volson Wood, Prof. of C. E. University of Michigan.

It is well known that, if certain omissions are made in a *Closed Survey*, they may be supplied from the remaining notes. I propose in this article to investigate the subject analytically.

I wish at the outset to express my acknowledgments to Mr. Cleveland Abbe, formerly a tutor in the University, and now connected with the United States Coast Survey, for the free use which he has permitted me to make of his notes upon this subject. His analysis covered nearly the whole ground, so that I have only to make slight additions and changes, and add geometrical illustrations, to put it in the form in which it is now presented.

In order to convert the bearings taken in the field into angles, which will be more convenient for our computations, we have

The bearing N $\beta°$E is equivalent to the angle $\beta°$
" " S $\beta°$E " " " $180°-\beta°$
" " S $\beta°$W " " " $180°+\beta°$
" " N $\beta°$W " " " $360°-\beta°$

and conversely an angle β being given we have when

$\beta° < 90°$ and $> 0°$ the bearing is N $\beta°$E.
$\beta° > 90°$ and $< 180°$ " " S $180°-\beta°$E.
$\beta° < 270°$ and $> 180°$ " " S $\beta°-180°$W.
$\beta° > 270°$ and $< 360°$ " " N $360°-\beta°$W.

Let l_1; l_2; l_3; &c., be the lengths of the known sides.
x_1; x_2 " " unknown sides.
b_1; b_2; b_3; &c., the known angles as found from the known bearings as given above.
β_1; β_2; . . the unknown angles.
D = the algebraic sum of all the known departures.
L = the algebraic sum of all the known latitudes.

Then for a closed field we evidently have

$$\left.\begin{aligned} \Sigma \text{ Dep.} &= l_1 \sin b_1 + l_2 \sin b_2 + \ . \ . \ l_n \sin b_n = 0 \\ \Sigma \text{ Lat.} &= l_1 \cos b_1 + l_2 \cos b_2 + \ . \ . \ l_n \cos b_n = 0 \end{aligned}\right\} \quad . \quad (1)$$

From which any two quantities may generally be found when all the others are known. We have several cases.

Case I.

Let One Bearing be Omitted.

Letting l=the length of any side, and we have from (1)

$$\left.\begin{aligned} l \sin. \beta_1 &= \text{D} \\ l \cos. \beta_1 &= \text{L} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

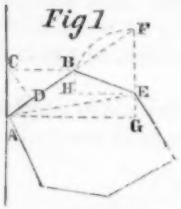
$$\therefore \text{sin. } \beta_1 = \frac{D}{l} \text{ cos. } \beta_1 = \frac{L}{l}. \quad . \quad . \quad . \quad . \quad (3)$$

and β_1 obtained from each of those must be the same. We also have tang. $\beta_1 = \frac{D}{L}$, which should give the same value as each of the others.

Eliminating l from (2) gives

$$D \text{ cos. } \beta - L \text{ sin. } \beta = 0 \quad . \quad . \quad . \quad . \quad (4)$$

These may be deduced geometrically; thus, let the bearing of AB, Fig. 1, be unknown.



Then CB = D. AC = L, and,

$$\text{sin. CAB} = \text{sin. } \beta_1 = \frac{CB}{AB} = \frac{D}{l}$$

$$\text{cos. CAB} = \text{cos. } \beta_1 = \frac{AC}{AB} = \frac{L}{l}$$

$$\text{tan. CAB} = \text{tan. } \beta_1 = \frac{CB}{AC} = \frac{D}{L}$$

From C let fall CD, perpendicular to AB. Then

$$CD = CB \text{ sin CBD} = CB \text{ cos. CAD} = D \text{ cos. } \beta_1$$

Also $CD = CA \text{ sin CAD} = L \text{ sin. } \beta_1$

By subtracting these we have $D \text{ cos. } \beta_1 - L \text{ sin. } \beta_1 = 0$

All these are the same as the analytical results.

Case II.

Let One Distance be Omitted.

Then Eq. (1) gives, if b be any angle,

$$x_1 \text{ sin. } b = D \quad . \quad . \quad . \quad . \quad (5)$$

$$x_1 \text{ cos. } b = L \quad . \quad . \quad . \quad . \quad (6)$$

$$\therefore x_1 = \frac{D}{\text{sin. } b} = \frac{L}{\text{cos. } b}$$

Squaring (5) and (6) and adding, gives

$$x^2 = D^2 + L^2$$

In Fig. 1, $AB = CA \div \text{cos CAB}$ or $x_1 = \frac{L}{\text{cos. } b}$

also $AB = CB \div \text{sin CAB}$ or $x_1 = \frac{D}{\text{sin. } b}$

also $AB^2 = AC^2 + BC^2$,
or $x_1^2 = L^2 + D^2$.

Case III.

The Length and Bearing of One Side Omitted.

From (1) we have

$$\left.\begin{aligned} x_1 \text{ sin } \beta_1 &= D \\ x_1 \text{ cos } \beta_1 &= L \end{aligned}\right\} \quad . \quad . \quad . \quad (7)$$

From these we readily find

$$\tan \beta_1 = \frac{D}{L}$$

$$x_1 = \sqrt{D^2 + L^2}$$

These results have already been illustrated geometrically.

CASE IV.

The Length of One Side and Bearing of Another Wanting.

For this Eq. (1) gives

$$x_1 \sin b_1 + l_2 \sin \beta_2 = D \quad . \quad . \quad (8)$$

$$x_1 \cos b_1 + l_2 \cos \beta_2 = L \quad . \quad . \quad (9)$$

Multiply Eq. (8) by $\cos b_1$ and (9) by $\sin b_1$ and subtract the results, and we find

$$l_2 \sin (\beta_2 - b_1) = D \cos b_1 - L \sin b_1 \quad . \quad . \quad (10)$$

from which we may find two values for $\beta_2 - b_1$, viz: $\theta°$ and $180° - \theta°$.

$$\therefore \quad \beta_2 = \theta + b_1 \text{ and } 180° - \theta° + b_1$$

From (8) and (9) we find

$$x_1 = \frac{D}{\sin b_1} - \frac{l_2}{\sin b_1} \sin \beta_2 \quad . \quad . \quad . \quad (11)$$

$$x_1 = \frac{L}{\cos. b_1} - \frac{l_2}{\cos. b_1} \cos. \beta_2$$

in which if both values of β_2 be substituted, we will obtain two values of x_1.

From (10) we find that β_2 (and therefore x_1) is imaginary when

$$\frac{D \cos. b_1 - L \sin. b_1}{l_2} > 1.$$

If $\beta_2 - b_1 = 90°$ there is only one solution.

If the second member of (10) is zero, we have $\beta_2 = b_1$; or the two courses coincide in direction, and we have from (8) or (9)

$$x_1 + l_2 = \frac{D}{\sin. b_1}$$

and the case is essentially the same as II.

To show this geometrically, we first observe that the two courses may be adjacent or separated. If separated, we may transfer the sides so as to bring the desired ones adjacent.

In fig. 1, let the length of AB and bearing of BE be wanting. Then by Case III compute the bearing and length of a line which joins A and E. Lay off the line AB according to the given bearing. Then with E as a centre and radius equal BE, describe an arc which will intersect AB in two points, B and F; hence there will be two lengths, AB and AF; and two bearings, one for BE, the other for FE. If the arc BF is tangent to AB, there will be but one solution; and if the arc does not touch AB, the solution is impossible, and the survey is not closed.

In the figure draw HE and AG perpendicular, and BH and EG parallel to AC. Then

$$AG = CB + HE,$$

or $$D = x_1 \sin. b - l_2 \sin. \beta_2.$$

The sign of sin. β_2 is minus because the angle is obtuse. From this equation we find

$$x_1 = \frac{D}{\sin. b_1} - \frac{l_2}{\sin. b_1} \sin. \beta_2 \text{ as before.}$$

CASE V.

Let the Lengths of Two Sides be Wanting.

Equation (1) gives

$$x_1 \sin. b_1 + x_2 \sin. b_2 = D \quad . \quad . \quad . \quad . \quad (12)$$
$$x_1 \cos. b_1 + x_2 \cos. b_2 = L \quad . \quad . \quad . \quad . \quad (13)$$

Multiply (12) by cos. b_2 and (13) by sin. b_2 and take the difference, and we obtain

$$x_1 = \frac{D \cos. b_2 - L \sin. b_2}{\sin. (b_2 - b_1)} \quad . \quad . \quad (14)$$

Similarly, $$x_2 = \frac{D \cos. b_1 - L \sin. b_1}{\sin. (b_2 - b_1)} \quad . \quad . \quad (15)$$

If these results are negative, the lines are imaginary and the solution is impossible—in other words, it is not a closed survey.

If $b_2 = 180 + b_1$, the unknown lines are parallel, and the denominator becomes zero; but the numerator also becomes zero at the same time—see (Eq. 4)—hence $x_2 = \frac{0}{0}$, which is undeterminate.

When a solution is possible there is no ambiguity.

In fig. 2, let the lengths of AB and BC be unknown. By Case III compute AC. Then draw AB and BC with the known bearings, and their point of intersection will give the point B, and AB will be the required length of one line, and BC of the other. If the bearing of BC should cause it to run in the opposite direction, it would not meet AB, and the solution would be impossible.

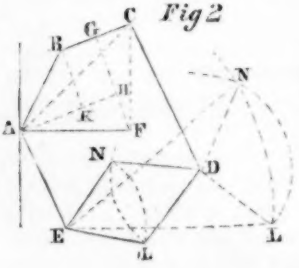


Fig 2

Draw AF perpendicular, and CF parallel to AM; AH parallel to BC, and FB perpendicular to BC. Then

$$BAH = b_2 - b_1.$$
$$BK = GH = x_1 \sin. (b_2 - b_1).$$
$$FG = CF \sin. BCF = L \sin. b_2.$$
$$FH = AF \cos. AFH = D \cos. b_2.$$
$$\therefore GH = FG - FH =$$
$$L \sin. b_2 - D \cos. b_2 = x_1 \sin. (b_2 - b_1).$$

$$\therefore x_1 = \frac{D \cos. b_2 - L \sin. b_2}{-\sin. (b_2 - b_1)} \text{ as before.}$$

If AE and CD are the unknown lengths, and are parallel, it is evi-

dent that the bearings and lengths of all the other lines may be the same for all lengths of these lines; provided only that they have a constant difference, hence they are indeterminate.

CASE VI.

Let the Bearings of Two Sides be Wanting.

Then $l_1 \sin \beta_1 + l_2 \sin \beta_2 = \text{D}$ . . . (16)

$l_1 \cos \beta_1 + l_2 \cos \beta_2 = \text{L}$ . . . (17)

These give $l_1 \sin \beta_1 = \text{D} - l_2 \sin \beta_2$.

$l_1 \cos \beta_1 = \text{L} - l_2 \cos \beta_2$.

Squaring these and adding gives

$$l_1^2 = \text{D}^2 + \text{L}^2 + l_2^2 - 2\,l_2\,(\text{D} \sin \beta_2 \mid\mid \text{L} \cos \beta_2).$$

Similarly $$l_2^2 = \text{D}^2 + \text{L}^2 + l_1^2 - 2\,l_1\,(\text{D} \sin \beta_1 + \text{L} \cos \beta_1).$$

In the first of these we might substitute $\cos \beta_2 = \sqrt{1 - \sin^2 \beta_2}$ and reduce, but the expression would be very lengthy. Instead of that we will make

$$\text{D} = m \cos \theta \quad . \quad . \quad . \quad . \quad (18)$$

$$\text{L} = m \sin \theta \quad . \quad . \quad . \quad . \quad (19)$$

and we shall find

$$\sin (\theta + \beta_2) = \frac{m^2 + l_2^2 - l_1^2}{2\,m\,l_1} \quad . \quad . \quad (20)$$

$$\sin (\theta + \beta_1) = \frac{m^2 - (l_2^2 - l_1^2)}{2\,m\,l_1} \quad . \quad . \quad (21)$$

From which we find two values for $(\theta + \beta_2)$ and two for $(\theta + \beta_1)$; hence there are two solutions. If $\theta + \beta_2 = 90°$ or $180°$, there is but one solution, and the two bearings will equal each other.

In fig. 2, let EL and DL be the sides whose bearings are unknown. With E and D as centres and radii equal the lengths of the sides describe arcs, and the points where they intersect will be the corners of the field. As they will generally intersect in two points, there will generally be two solutions. EN or EL will be one side; and DN or DL the other. If the arcs are tangent to each other there will be but one solution, and the two sides will coincide in direction.

As an illustration of the manner of using these equations, take the following examples, found in Gillespie's Surveying. In Article 441 of his Surveying we have given

$\text{D} = -5314{\cdot}34587$ $\qquad$ $l_2 = +4621{\cdot}5$

$\text{L} = -1405{\cdot}32477$ $\qquad$ $b_1 = 198°$

This problem belongs to Case IV.

Now apply Eq. (10).

D cos b_1	=	+ 5054·244
L sin b_1	=	+ 434·269
log of dif.	=	3·664641
log b_2	=	3·664783
$\therefore$ log sin $(\beta_2 - b_1)$	=	9 999858
$\therefore$ $\beta_2 - b_1$	=	88° 32′ or 91° 28′
$\therefore$ β_2	=	286° 32′ or 289° 28′

Corresponding bearing is N. 73° 28′ W., or N. 70° 32′ W.
Now use Eq. (11).

Log sin	β_2 =	n 9·981662	or	n 9·974436
Log l_2	=	3·664783		3·664783
Sum of log	=	n 3·646445		n 3·639219
Log sin b_1	=	n 9·489982		n 9·489982
Log D	=	n 3·725450		n 3·725450
D cosec b_1	=	+ 17197·6		+ 17197·6
l_2 sin β_2 cosec b_1	=	14337·16		14100·58
∴	x_1 =	+ 2860·44	or	+ 3097·02

For an example under Case VI, take the one in Article 448 of Gillespie. We have

D = + 1479·75010 $\quad$ l_1 = + 2400
L = — 2303·26591 $\quad$ l_2 = + 2860

Apply Eqs. (18), (19), (20), and (21).

Log. m sin. θ	n 3·362344		l_2^2 + 8179600
log. sin. θ	n 9·924967	log. m 3·437377	l_1^2 + 5760000
log. m cos. θ	3·170189	log. m^2 6·874754	
			+ 2419600
θ =	302° 43′ 8·7″		m^2 + 7494700
log. $(m_1^2 + l_2^2 - l_1^2)$	6·996262	log. $(m^2 - l_2^2 + l_1^2)$	6·705445
av. comp. 2 m_2	6·261613		6·261613
av. comp. l_2	6 543634	av. comp. l_1	6·619789
sin. $(\theta + \beta_2)$	9·801509	sin. $(\theta + \beta_1)$	9·586847
∴ $\theta + \beta_2$ =	39° 16′ 59·2″ or 140° 43′ 0·8″	∴ $\theta + \beta$ =	22° 43′ 22·6″ or 157° 16′ 37·4″
θ =	302 43 8·7 or 302 43 8·7		302 43 8·7 or 302 43 8·7
β_2 =	96 33 50·5 or 197 59 52·1	β_1 =	80 0 13·9 or 214 33 28·7

Bear'g = s 83° 26′ 9·5″ E or s 17° 59′ 52·1″ W. Br'g. = N 80° 0′ 13·9″ E or s 34° 33′ 28·7″ W

MECHANICS, PHYSICS, AND CHEMISTRY.

Steam Engine Economy.

From the Lond. Mechanics' Magazine, Jan., 1864.

A patent case has recently been tried at Washington, U. S., which has elicited certain statements so remarkable in their bearing on the system of steam engine construction adopted of late in the American Navy, that we cannot pass it without notice. The case in question is simple enough in itself. A Mr. Mattingly, of Washington, sued a steamboat company for a share of the savings effected by a peculiar form of cut-off valve, the patent right in which he held, and had sold to the company, taking a share of the savings effected as the pecuniary consideration. The defence set up was singular enough. The complainant asserted, and as he believed proved, that the saving in fuel amounted to over 30 per cent., and he demanded a verdict in accordance with his statement. The defendants, however, called Mr. Benjamin Isher-

wood, the Chief Engineer of the United States Navy, to prove not only that the particular cut-off which afforded the *casus belli* could not possibly effect the alleged saving; but that the only possible saving which could be effected by that, or any other cut-off, amounted at the maximum to 18 per cent., and that, therefore, a saving of thirty per cent. was a physical impossibility. This statement is startling enough; but Chief Engineer Isherwood does his work thoroughly; and he proceeded to strengthen his evidence by swearing that no one believed his "new discovery" to be true, until 1860, and that since then all the new marine engines for the navy were built and building upon it. It is nothing new to us to learn that American engines generally are constructed without much regard to the strict principles which can alone secure economy. The indicator and its use are almost unknown in the States. This little instrument affords the only known means of ascertaining the exact duty performed by steam within a cylinder; and in its absence, we can only form a vague idea of the really useful effect produced by the combustion of fuel. A constant habit of observation, and a thorough practical acquaintance with a large number of steam engines of different constructions, working under varying conditions, can alone give that knowledge which will permit us to build engines capable of doing a large duty with little coal. This knowledge is tolerably well-diffused throughout the workshops of Great Britain; the young engineer being generally afforded every opportunity for testing the actual performance of engines by the aid of the indicator. More can be learned in this way in half-an-hour than can be derived from theoretical instruction, however good, in a year; and we cannot expect men who are almost, or altogether, unacquainted with the nature and properties of the instrument, to turn out first-class engines. It is very probable that we shall be accused of attaching an undue importance to so small a thing. Those who have studied the subject will take a different view of the matter, and will, without doubt, endorse a statement which will bear repetition—namely, that, without the use of the indicator, there can be no real knowledge of what does or does not constitute a good engine. Until its use extends in America, we do not look for much improvement in steam engineering. Although our Western friends are somewhat lax in their practice elsewhere, we did not expect that their navy would afford such precedents as Mr. Isherwood's evidence indicates—evidence, too, which comes upon us with all the force which can be conferred by an oath, and all the strength which can be derived from the high position of the swearer. Mr. Isherwood has, we fear, led many a feeble mind astray. The engineers of Washington possess a great deal of common sense, however Mr. Mattingly's friends sent to New York for Mr. Dickerson, an adept in the engineering, and a man learned in the law as well—a combination of professional attainments all too rare in England. Mr. Dickerson's powers of cross-examination threw a new light on the subject, from which it appears that the "red tapeism" is all-powerful in the Naval Department of President Lincoln's Administration. To a final suggestion, that the question should be fairly put to the test on the river Po-

tomac, in presence of judge and jury, the defendants turned a deaf ear. The experiment was made, notwithstanding, on board the steamship "Collyer;" when it turned out that with 600 lbs. of coal an hour, she could run at the rate of twenty-seven revolutions a minute with expansion, and that but twenty a minute could be got without expansion, and with 700 lbs. an hour. This evidence was deemed so conclusive that a verdict was at once given for the complainant.

It is not difficult to imagine what English engineers will think of all this. Mr. Isherwood's evidence is opposed to all theory and all practice, that, did he hold a different position, or were he less talented, his word would simply be passed over with a smile, or, perchance, a hearty laugh. The value of expansion, properly carried out, is pretty well understood among us; and it would be unfair to deny that many American engineers attach a proper importance to the principle as well. When the chief engineer of a great navy gives utterance to sentiments and opinions so widely opposed to those held by other experts, a natural curiosity is experienced to know where he got them. We will try and enlighten our readers.

In the early part of the year 1860, the United States Navy Department, in the plenitude of its wisdom, deemed it right that certain experiments should be made to determine the relative economy of using steam with different measures of expansion. Not content with the evidence afforded them by the practical operations of the Cornish pumping engine, the locomotives on the New York railroads, or the marine engines in use on the rivers and seas of the Western Continent, the gentlemen of the Department resolved on instituting thorough experimental research into the whole subject, and with this object in view, they appointed Chief Engineer Isherwood and three other engineers, as a committee, to make the experiments. As very valuable results were anticipated, it is natural that we should suppose that more than one engine was reported on; that the best engines in the navy would be selected, and the necessary data derived from the performance of the engines tried, at sea, under the ordinary conditions of working first, and, subsequently, under such extraordinary conditions as seemed best adapted to the attainment of the end in view. Such a conclusion is not more natural than erroneous. But one steamer, the "Michigan," was selected. At the time of the experiments, February, 1860, she was out of commission, frozen up in Lake Erie; the hull had been recently repaired, and the old boilers replaced with new ones, constructed on Martin's patent, with vertical water tubes, instead of horizontal flues over the furnaces. The engines were two in number, of a form not much known in England; the cylinders, 36 ins. in diameter, and having a stroke of 8 ft., lying in an inclined position, and at an angle of 28 deg. with the keel. Not content with confining the experiment to the narrow basis afforded by a single steamboat, Mr. Isherwood and his colleagues still further restricted it, by retaining only one of the two cylinders in use; the other being uncoupled from the crank-shaft, and put out of communication with the boilers. The valves were of the ordinary double beat poppet kind, habitually used in American

paddle engines. The steam valves were made to act as expansion valves, by means of an arrangement, known as "Sickles' cut-off." The distance between the boiler and the engine was 25 ft.; and the total length of the steam-pipe over 17 ins. in diameter, exposed to the refrigerating influence of the atmosphere, was 30 ft.; and the pipes being set on a slight incline, the water of condensation naturally found its way into the cylinder. The steam-pipes were clothed with felt and wood lagging. The heads of the cylinders, the valve chest, and the long nozzles, peculiar to this form of engine, were without covering of any kind. It is needless to enter into any minute detail of the experiments. We have already alluded to Mr. Isherwood's talents, and he spared no trouble to obtain exact results from the engine under trial. The vessel was moored fast, the ice cut away from about the floats, and the whole power of the engine exerted in paddling the water backwards. Each experiment lasted 72 consecutive hours, during which the engine was neither slowed nor stopped. We have dwelt on Mr. Isherwood's proceedings in this matter at some length, because very little about them is known in this country that we are aware of, although they have attracted a great deal of attention in the States already, and are likely to attract very much more. Let us hasten to the results. With the steam cut off at $\frac{1}{12}$ths of the stroke, the consumption of coal amounted to 4·847 lbs. per hour; cut off at $\frac{1}{10}$ths, to 4·324 lbs.; at $\frac{1}{8}$ths, to 3·725 lbs.; at $\frac{3}{10}$ths, to 3·677 lbs.: at $\frac{1}{4}$th, to 3·428 lbs.; at $\frac{1}{3}$th, to 3·801 lbs.; and at $\frac{4}{5}$ths, to 4·281 lbs. From these results we find that the gain by expansion is decided up to a cut-off at $\frac{1}{4}$th of the stroke, and that there is no advantage to be derived from expansion afterwards, *with the particular engine under consideration.* The results perfectly satisfied Mr. Isherwood. He prepared a very elaborate report—a model of its kind—in the course of which he attempts with much plausibility, to upset Marriott's law as applied to the expansion of steam, and laid it before the Hon. Isaac Toucey, Secretary of the Navy. As a result, it now appears, from the Washington investigation, that the engines for the American Navy have been, almost from that day forth, constructed without any regard to the carrying out of the principles of expansion. The crop thus sown will be reaped ere long in diminished speed, and increased coal bills.

If the engine of the "Michigan" had been specially designed to prove that the advantages of expansion were a delusion, it could not possibly have been better adapted to that end. Mr. Isherwood is a careful and, we presume, a conscientious experimenter; but all his conclusions in this case are vitiated by being drawn from false premises. He has recently published a large and handsome volume,* to which we may have occasion to refer again, a large portion of which is taken up with a detailed account of these experiments and their analysis. It required little penetration to see where the author has lamentably failed to make out his case. No provision whatever, either by superheating or otherwise, was made to prevent condensation in the cylinder of the "Michigan's" engine. The length of the stroke was 8 ft.;

"* Experimental Researches in Steam Engineering," by B. F. Isherwood, Chief Engineer U. S. Navy, Hamilton Brothers, Philadelphia; Baillier Brothers, New York.

the number of double strokes per minute, with the steam at full pressure, was a little over 20; with the steam cut off at ¼th, rather less than 14. The steam had to traverse some 30 ft. of steam pipe, lightly clothed, in an atmosphere only raised above 29 deg. by the heat abstracted from the engine and boilers, to be subsequently isolated for a space of three or four seconds at a time within a cylinder, lagged, it is true, at the sides, but wholly exposed to the atmosphere at the ends. The cylinder was 3 ft. in diameter, the area of each lid was over 7 square feet. It requires no very abstruse calculation to point out the value of this area as a refrigerator during each tedious stroke. Then, we have the valve chests and nozzles all aiding the same work. Nor is this all. Mr. Isherwood, on his own showing, proves that the loss due to clearance and nozzle space in the "Michigan's" engine amounted to a positive reduction of average pressure equal to 12 per cent. when the steam was cut off at ⅛th of the stroke, and to nearly 8 per cent. when the cut-off took place at ¼th of the stroke. Some men are so mentally constituted that they only regard any fact from one point of view. Instead of gathering from his experience that it was advisable that clearance of all kinds, should be reduced to a lower limit than that found in the particular engine experimented on, Mr. Isherwood, with a strange perversity, takes this very loss of pressure as evidence that expansion is wasteful in practice, and should not be employed! Our readers can form their own estimate of the value of conclusions so arrived at.

It is doubtful if the history of nations can show a more astounding instance of folly in a case where the safety of a country was involved, and that country actually at war, than that presented by the recent proceeding of the Bureau of American Marine. On the evidence afforded by series of experiments on a single engine in an old and small steamer on an inland lake, conducted by four engineers, far removed from supervision of any kind; the engine being, on the showing of those most interested in proving the reverse, totally unsuited in every respect for the application of expansion—the piston moving at but 176 ft. per minute, and the steam not superheated in the slightest degree—those in authority have determined, in their wisdom, to set aside all the teaching of the last fifty years. They have wilfully shut their eyes to the work of improvement going on daily in England and France, and have, with a temerity almost without a parallel, staked the future of a great navy and enormous sum of money on the truthfulness of a single obscure experiment, bearing but a remote analogy in its conditions to those under which steam should properly be employed. It is as though the American engineering world had retrograded the third part of a century. We shall expect, next, to hear war steamers denounced, and the old liner pronounced just the thing to defend the interests of the people, or push on a war of aggression on distant shores. Americans are very clever. They have taught us many things. This time, in the attempt to teach the world something new, they have overshot the mark, and only repeated an old story in our ears—the story of human folly.

On the Effects of Surface Condensers on Steam Boilers.

By Mr. James Jack, of Liverpool.

From Newton's London Journal of Arts, February, 1864.

Some three or four years ago condensation of the exhaust steam from marine engines by surface contact was looked upon as an experiment, and few steamship owners could be induced to try this system, which was new to them: and notwithstanding the development and complete success of tubular surface condensers, both in the merchant ships and in the navy, more than a quarter of a century ago, and the reduction thereby effected in the consumption of fuel, the objection was raised that surface condensation could not have the advantages alleged, or it would never have been discontinued. At the present time, however, it is no longer an experiment, but a reality; for not only have surface condensers been largely introduced with new engines, but in many cases injection condensers have been taken out of working vessels, and surface condensers put in their place. As the writer's firm has constructed and fixed a considerable number of surface condensers during the last three or four years, and as certain actions have been found to take place on the tubes and plates of the boilers with these surface condensers, of such a character that the full advantages of the use of distilled water could not with impunity be obtained, it is the purpose of the present paper to give the particulars of these effects, and thus to induce discussion upon the subject, and elicit information which will enable the great advantages in the saving of fuel resulting from the employment of surface condensers to be appreciated. As the boilers, where surface condensers are used, are insidiously and rapidly acted on, the danger of delay and of accident from explosion is thereby greatly increased,—rendering the question one of serious importance.

Surface condensation may be considered an old idea; for Savery adopted the principle in 1690, in what may be called the first steam engine—having applied cold water to the outside of the cylinder; and even Watt devoted much time to it, although he afterwards finally abandoned it—stating that the objection of the size and expense of the tubular condenser for large engines made him resolve to sacrifice part of the power to convenience, and to employ large pumps. It was about 1832 that surface condensation became practically carried out. Mr. Samuel Hall, having seen its advantages, constructed a surface condenser, consisting of a casing containing a number of small tubes; and succeeded in overcoming the difficulty of making a tight joint between the water and steam spaces, which should allow for the expansion and contraction of the tubes. These condensers were introduced into both naval and mercantile ships; but, although attended with considerable advantages, they ultimately fell into disuse. Several modifications have since been proposed with different arrangements and constructions of the tubes, with the water inside instead of outside the tubes, or with a combined jet and surface condensation. There was a difficulty at first in obtaining some effective packing for the ends

of the tubes: but after the long experience of India-rubber for the purpose, it may now be pronounced a success; for out of many thousands of joints which the writer's firm have made, not a single case of leakage has occurred.

Surface condensation is a process by which both the sensible and latent heat of the steam are conveyed away; and although the adoption of any new system is necessarily slow, the writer does not doubt but that surface condensation will ultimately entirely supersede the jet. There are evils, however, which require remedying before surface condensation can be universally adopted for steamships—not in the condenser itself, but in the effects produced on the boilers by distilled water or something contained in it resulting from surface condensation. The writer will accordingly refer, first, to the effects of surface condensation on the boilers, and, secondly, to the probable cause of this destructive action.

A number of marine boilers which have come under the writer's observation, and may for convenience be distinguished by the letter A, had been in use for longer or shorter periods, none less than six months, supplying steam to engines having injection condensers. Salt water had been used for feeding the boilers, and a considerable incrustation had consequently taken place. Without going to the trouble and expense of cleaning these boilers, they were sent to sea immediately after the surface condensers were fitted in. Everything went on satisfactorily, and on returning from the first voyage, the boilers were examined. It was found that the greater portion of the incrustation had fallen off, and that the surfaces of the boilers—that is the inner surfaces—were in very good condition for transmitting heat; showing that the adoption of distilled water for feed had been advantageous. Boilers of this class have uniformly had the incrustation nearly all removed by the action arising from the use of the surface condensers during the first voyage, and in every case the surfaces of the boilers have been found in good condition and still remain so, some of them now for as long a term as four years. Indeed surface condensation has here been in every sense a decided success.

The appearance of the inside of the boilers, however, was not that of clean iron. The surface seemed to be impregnated with some greyish matter, or to be altered in its chemical nature. That this impregnation or alteration of the surface prevented, and still prevents, injurious action on the metal, will be gathered from a description of another lot of marine boilers, distinguished by the letter B, which were in all cases new boilers—sometimes with new engines and surface condensers, in other instances with old engines and new surface condensers. In port, before starting, a number of these boilers were filled with fresh water, while another number were filled with salt water. An examination after the first voyage, during which only distilled water had been used for feeding the boilers, showed the following effects, which were increased in every subsequent voyage, until the practice was adopted of feeding with, say, from one-sixth to one-tenth of salt water. First, both above and below the water-line the surfaces of the plates, tubes,

and rivets were covered with a deposit resembling hydrated oxide of iron, which, when the water was evaporated, was in the state of a fine impalpable brownish colored powder. This deposit was thickest above the water-line, sometimes averaging ¾-inch thick. When the boilers were emptied, a thick slimy deposit adhered all over the inside, an analysis of which showed that it consisted of—

Oxide of Iron	77·50
Moisture	19·75
Grease	0·85
Sulphate of Lime	0·80
Oxide of Copper	0·60
Traces of Alumina and Chloride of Sodium and Magnesium	
Loss	0·50
	100·00

Secondly, underneath this deposit the plates and tubes were found to be eaten into, indented, or "pitted." The indentations varied in diameter, from the smallest speck to ⅝-inch, and in depth from the merest impression to the entire thickness of the plates or tubes. And although they were formed all over the boilers, they were most frequently found and were most numerous just over the fireplaces, and in those parts immediately in connexion with the greatest heat. In some of these parts, the surface was entirely covered with the indentations; while in other parts, as much as a square foot of plate, although subjected to the greatest heat, was free from them. The plates and, tubes in all cases, have been of the best iron, and by good makers; and the "pittings" occur in what looks like iron of good quality with a good fibre; no slag or cinder being perceptible. So destructive was this pitting in boilers using the same water over and over again, that in one instance, the tubes of new boilers were actually eaten through at the end of two or three voyages, extending over only a few months altogether, and it became necessary to put in new tubes, and to use a portion of salt water for feed to keep up an incrustation, so that the boilers should not be acted upon. If the iron of the boilers had been all of one make, it would naturally have been concluded that the pitting was due to the quality of the iron; but as the iron of different boilers had been obtained from different makers from time to time, the quality of the iron could not be blamed.

The presence in the boiler of a soft metal—such as copper from the condenser tubes—it was considered, would induce a galvanic action such as might affect the iron in some way. But the analysis which was made of the deposit scraped from the boiler, shows that there was scarcely a trace of any foreign metal there. Indeed, it might have been concluded, that a soft metal could not be present; for the tubes of the condenser and the copper pipes were all in a perfect condition. Even at the joints, made tight by India-rubber, hardened by vulcanizing, there was scarcely a speck of corrosion.

A search was then made to ascertain whether the gluey deposit was present that arises from the decomposition of the tallow and oil used for lubrication; as the writer had frequently heard that such a deposit

took place in boilers where Hall's surface condensers were used. For the purpose of ascertaining this, the mud cocks of a vessel were not opened for some time before arriving in port; and the fires were then put out on arrival, and the mud discharged, when the only substance found was the watery-brownish deposit before referred to. The deposit remaining in the bottom of the boiler was carefully examined, but here again there was only the same deposit. As it was believed that the lubricating material carried into the boilers with the feed might, by continued subjection to heat, form an acid capable of producing the effects observed, the kind of lubricating material employed was noticed, in order to ascertain whether animal or vegetable oils acted most injuriously; but it was found that the action went on as much with the one oil as with the other. In case, however, a fat acid, formed as already mentioned, might be the cause, pieces of chalk were put into the boilers, and from time to time fresh pieces were added; carbonate of soda was also mixed with the feed water in regular doses: but all to no purpose, the action went on, getting worse and worse.

No alternative was therefore left, nor is there at present any other, as far as the writer has been able to learn, but to feed the boilers with a portion of salt water sufficient to keep a thin incrustation over the surface of the iron. It was suggested that the deposit was nothing else than rust or oxide of iron, and that it was formed by the chlorine present in the small proportion of salt water, which would combine with the iron to form chloride of iron; and this being readily decomposed by oxygen, oxide of iron would result. The difficulty here, however, was to know whence the oxygen was obtained; for the quantity of air entering with the feed water must have been very small indeed. It was also suggested that hydrochloric acid might be present from the small quantity of sea water that may have found its way into the boilers; but then the difficulty was to know where a quantity of the acid was to come from sufficient to act over such an extended surface, and so rapidly as the results showed.

It was found, however, by Mr. Rollo, one of the writer's partners, that in a pair of boilers at a sugar refinery, there was the same brownish deposit adhering all over the boilers, and those parts subjected to the greatest heat were "pitted" in precisely the same manner as the second lot of marine boilers previously designated by the letter B. Exactly the same effects were being produced. These boilers were supplied with the same water over and over again, a small quantity of fresh water being added from time to time to make up for the loss. As the steam was passed only through iron pipes for melting the sugar, the damage to the boilers could not result either from the steam coming in contact with a soft metal, or from any lubricating material. The boilers were of the Cornish construction, with one flue, and were worked at about the same pressure as the marine boilers B already referred to, say 20 lbs. per square inch pressure. A pair of boilers, of exactly the same construction, placed alongside the first pair and working at about the same pressure, but fed with water which had not been distilled, were then examined, to learn what state they were in. But,

although put in about the same time as the two first examined, these boilers were found in good condition and likely to last for years, as there was not a sign of corrosion or "pitting;" whereas the two boilers working with distilled water had to be repaired.

The practical knowledge thus acquired necessarily led to the conclusion that the distilled water itself was the cause of the corrosion, instead of any galvanic action or any fatty acid. In reference to the question whether distilled water has any particular action on metals, the chemist Berthier found that nodular protuberances deposited on iron pipes containing distilled water consisted of 21 per cent. of protoxide of iron, 58 per cent. of peroxide of iron, 5 per cent. of carbonic acid, 14½ per cent. of water, and 1⅓ per cent. of silica. The iron pipes contained also a perverulent substance, which could be produced at pleasure with distilled water to which a trace of carbonate of soda and common salt had been added, but not with an addition of caustic alkali. Distilled water is known to act powerfully on lead, and this action is attributed by Dr. Clark to the remarkable property that distilled water has, as compared with ordinary water, of dissolving free carbonic acid.

The writer does not presume to state confidently that distilled water is really itself the active destroyer of iron boilers; but, from the observations that have now been referred to, and the information he has been able to obtain, he thinks there is sufficient evidence that distilled water is, if not the sole cause, at least an active agent in producing the corrosive effects that have been described. If this suggestion should lead to the remedy of the evils that have been experienced where distilled water alone has been used, another difficulty will have been overcome towards the complete introduction of surface condensers.

Mr. J. Ramsbottom said he had been much interested in the paper just read, and the conclusions arrived at coincided with the results of his own experience with stationary and locomotive engines, not with distilled water, indeed, but with peat water, which was almost as pure as distilled water. He had been informed that the boiler of the winding engine which formerly worked the Woodhead Tunnel on the Sheffield and Manchester line was corroded through in a very short time, being fed exclusively with the peat water from the Yorkshire moors; and on putting down a second boiler in its place, the precaution was taken of mixing with the peat water a portion of water from one of the shafts, the result of which was that the corrosion was almost stopped, but an incrustation of deposit was then formed inside the boiler. In the same range of hills he found that the locomotives working the Huddersfield and Manchester line, with almost pure water, had their boilers corroded in the same way; and he had now adopted the plan of putting a portion of carbonate of lime in the tanks, to prevent the corrosion.

Mr. C. Markham had also found the use of nearly pure water injurious to boilers, and the evil effects continued until the interior of the boiler became sufficiently coated with calcareous matter to prevent the corrosion going on. The effect produced by using pure water in boilers

that had previously been worked with water containing a great quantity of lime was very remarkable: some of the locomotives on the Midland Railway were supplied with water that contained much lime, causing a great deposit in the boilers; and when any of these engines were sent down to Sheffield, where the water came from the moors and was very pure, the effect of the change was that the deposit was speedily removed in large masses; and he had seen a barrowful of the calcareous matter removed and washed out of a locomotive boiler after it had worked for a single day with the Sheffield water. So long, however, as an incrustation of lime remained on the plates, it had the advantage of protecting them from any injury by corrosion from purer water.

Mr. J. McF. Gray thought the "pitting" observed in the case of locomotive boilers working with pure water was due to the brass tubes used in the boilers: for, on examining the pitted plates by the microscope, he had detected a minute speck of brass in the centre of so many of the "pits" as he thought would warrant the conclusion that this was the cause of all the pitting, in consequence of the galvanic action produced by the particles of brass. The corrosion of the iron had accordingly been prevented in those cases by suspending a piece of zinc among the boiler tubes, which neutralized the action of the brass. The pitting had not been so extensive in the hottest plates of the boilers as in other parts, because at the hottest parts the ebullition of the water was more violent, so that there was less facility for the particles of brass becoming deposited there upon the plates to cause the corrosive action. From the paper it appeared not to be expected that distilled water would be able to be used successfully in boilers: but if the difficulty arose merely from the water used being distilled water, it might easily be got over by aerating the water, since the only difference in distilled water was, that it was not charged with air like ordinary water. The real objection, he considered, to surface condensation was that the same water was then used over and over again without change; and he thought this must be the reason of the corrosion observed in the boilers of sugar refineries, the steam being condensed over the surface of the evaporating pans, whereby the water became in course of time impregnated with particles of brass or copper from the pans and pipes, gradually accumulating in the unchanged water. In the sugar plantations of the West Indies, where there was a difficulty in getting fresh water, and the same had to be used over and over again, the water was found to get sour, as it was termed, and became more and more injurious to iron, the longer it was used without change. He therefore thought the corrosion observed was to be attributed to the specks of brass carried into the boiler by the water where there was surface condensation of the steam.

Mr. D. Rollo observed that the object of the paper was not to discourage the use of surface condensation, but to point out the difficulties that had been met with in its application, with a view to ascertaining how they could be removed. With regard to the boilers at the sugar refinery that had been referred to, the corrosion could not, he

thought, have been caused in that case by the presence of brass particles in the water; for the steam passed only between the two cast iron plates of the evaporating pans, and when condensed, returned again to the boiler, without coming in contact with any brass at all in the apparatus, the leakage being made up by the addition of a little fresh water. There were four boilers, all working together,—two fed with the distilled water returned from the evaporating pans and two with fresh water: the two latter, at the time of examination, were found in perfect condition after four years work, having only a large deposit or scale of lime over the surface of the iron; while the other two fed with the distilled water, after the same time of working, had become quite unsafe from corrosion, and had to be very extensively repaired. They had tried various remedies for the evil; suspending zinc plates in the boilers, but with what result had not yet been ascertained; cast iron pipes instead of copper pipes for conveying the steam; and tinned tubes, zinc, and galvanized-iron tubes in the condensers instead of brass. Block tin tubes had also been tried, but were found not to have strength enough to support their own weight when placed horizontally. All these trials therefore still left the question of the cause of corrosion undecided: but he thought it could not be the action of copper, because the analysis that had been made of the deposit found in the boilers using surface condensers showed a very small proportion of copper, the main metallic ingredient being iron, and there was not sufficient copper collected from the boilers in the voyage of a steamship to account for such an extent of corrosion as was met with. Where much grease, however, was used in the engine, he had seen the inside of a boiler present an appearance which he thought rendered it just possible that the fatty matter or acids contained in the grease had something to do with deteriorating the quality of the water and causing its corrosive action.

Proceedings Mech. Eng. Society, August 2, 1863.

Steel Ships.

From the Journal of the Society of Arts, No. 576.

Two large ships, built of steel plates, were recently launched in the Mersey. Though some small vessels have been built of the same material, this is the first instance in which steel has been used for ocean ships. The steel now manufactured for shipbuilding purposes is said to have an advantage over iron, in being more ductile and malleable, as well as stronger and lighter. These qualities bring with them, it is also said, greater economy in building and increased capacity, both most important considerations. Mr. Jones, one of the builders, states that in the *Formby*, one of the newly-launched vessels, of 1276 tons burden, the weight of steel used is 500 tons, whereas, if she had been constructed of iron, 800 tons of that metal would have been required. In a vessel like the *Warrior*, he declared that by using steel greater strength might be obtained with a saving of one-half in the weight of metal. Mr. Reed, Constructor of the Navy, made a special journey from London to attend the launch and examine the ships. He remarked

that merchant ships can be built to test a principle, when war ships cannot, as the former can be examined and repaired annually, while the latter are sent abroad for periods of three or four years. He perfectly agreed with what had been said of the importance of steel for the construction of small ships, and stated that the Government took great interest in the question of employing steel as a material for shipbuilding.

Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.

From the Journal of the Society of Arts, No. 554.

(Report of the Chief Engineer, April 28th, 1863.)

During the past month there have been examined 288 engines and 406 boilers. Of the latter, 6 have been examined specially, 11 internally, 79 thoroughly, and 310 externally; in addition to which, 2 have been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 5 (one dangerous); corrosion, 30 (one dangerous); safety-valve out of order, 1; water-gauges, ditto, 8; pressure gauges, ditto, 9; feed apparatus, ditto, 1; blow-out taps, ditto, 32; furnaces out of shape, 4; over-pressure, 4; blistered plates, 4.—Total, 98 (two dangerous). Boilers without glass water-gauges, 6; without blow-out taps, 13; without back pressure-valves, 21.

Some explosions occur at too great a distance from Manchester to admit of a personal investigation, and of these little or no reliable information can be obtained at the time. Of one such which took place last year, and of which the fact of its occurrence only was therefore recorded in the reports, there has since been, through the kindness of the engineer who investigated the explosion immediately after it happened, full information with regard to it, as well as a drawing of the boiler after rupture, both of which are placed at the disposal of the Association. From these it appears that the boiler in question was of plain Cornish construction, and that the explosion resulted from collapse of the internal flue tube.

The explosion was attended with fatal consequences, the rush of steam and water from the flue blowing down the end wall of the boiler-house, abutting against a public thoroughfare, in which the workmen of the establishment, most unfortunately, were assembling around the gates of the premises, a few minutes before bell time. The steam, water, and bricks were all scattered amongst the group, and five lives sacrificed.

The length of the boiler was 26 feet; the diameter of the shell, 7 feet; that of the internal flue, 4 feet; and the thickness of the plates in both, three-eighths nominally, while at the centre of the flue it was found, after the explosion, to have been but little more than one-quarter. The boiler had been purchased second-hand, while the workmanship is reported to have been inferior, and the flue tube, though supposed to be circular, to have proved actually oval at the middle of its

length. This flue was not strengthened by flanged seams or hoops, while the working pressure was 50 lbs. to the square inch.

Under these circumstances it is clear that the simple weakness of the flue was the cause of the explosion, which must, therefore, be added to the already long list of those which could have been prevented by the simple precaution of strengthening the flue, either with flanged seams or hoops, while the weakness could not have escaped detection on competent inspection, or practical exposure on the application of the hydraulic test.

No. 6 explosion, like the preceding one, occurred at a considerable distance from Manchester, and although it took place last month, was only reported within the last few days; and there has as yet been no opportunity of obtaining further particulars with regard to it than that the boiler was of plain cylindrical, egg-ended construction, externally fired, and was thrown by the explosion to a considerable distance from its original seat, which is always the case with this description of boiler.

Neither of the two boilers just referred to were under the inspection of this Association.

Three explosions have occurred during the past month to boilers not under the inspection of the Association, by which nine persons were killed, and four others injured. All of these explosions occurred so far from Manchester that only one of them—viz: No. 8, which was by far the most important—had been personally investigated.

The following is the monthly tabular statement:—

TABULAR STATEMENT OF EXPLOSIONS FROM MARCH 28, 1863, TO APRIL 24, 1863, INCLUSIVE.

Index No.	Date.	General Description of Boiler.	Persons killed.	Persons injured.	Total.
No. 7.	April 7.	Plain cylindrical Externally fired, .	0	0	0
No. 8.	April 8.	Four cylindrical egg-ended Externally fired, . . . One ordinary single flue or "Cornish" Internally fired, . . (These five boilers all exploded simultaneously.) . .	9	4	13
No. 9.	"	Plain cylindrical Externally fired, .	0	0	0
Total,	.	. . .	9	4	13

No. 8. *Explosion.*—This explosion occurred at an iron-works, and is one of the most remarkable that have come under the notice of this Association—five boilers, working side by side, having in this instance exploded simultaneously, the shells of all of them being rent asunder, and thrown to a considerable distance from their original brick-work setting, which was completely destroyed, and reduced to a heap of ruins. The fragments and boiler fittings were shot in every direction, many of them falling through the roofs of the adjoining buildings, and one through that of the dwelling-house of the proprietor. Two of the

boilers were thrown over a tramway, and landed in a ploughed field beyond; one of them raking the rails in its course, cutting them completely through at the solid metal, and tearing up the roadway, a piece of one of the rails, that had been shorn off, being carried away to a distance with the boiler.

The five boilers were ranged side by side, all of them being connected, both by the steam-pipe and feed-pipe. Their direction was very nearly north and south, the furnaces being at the south end. No. 1 boiler, commencing at the west, was of Cornish construction and internally-fired, while the remaining four were cylindrical, with egg-ends, and externally-fired. The length of all the boilers was about 25 feet, while the diameter was 6 feet in No. 1, and 5 feet in the remaining four, the thickness of the plates being seven-sixteenths in the former, and three-eighths in the latter. The boilers were each fitted with one feed-back pressure-valve and feed stop-valve combined, one glass water-gauge, one alarm low-water steam whistle, worked by a float fixed inside the boiler, and one lever safety-valve, of 4 inches diameter, in addition to a Bourdon's pressure-gauge fixed on the steam-pipe at some distance from the boilers. The safety-valve admitted of nearly 60 pounds per square inch, but it was stated that 45 pounds had been the limit at which the boilers had been worked, since the weight had always been placed at some distance from the end of the lever. Even the higher pressure, however, would not have been excessive for boilers of such dimensions, as far as the cylindrical shells are concerned.

The rents were extremely complicated by the effects of the explosion, and although highly important to do so, it is in these cases difficult to determine which are the rents from which the explosion sprung, and which are those that resulted from it; or otherwise, which rents are the primary ones, and which the secondary ones. It appeared, however, that all the egg-ended boilers had rent in two, transversely, one portion flying northward and the other southward, the rent occurring at one of the transverse seams over the furnace, while the larger portion had in every instance flown northwards. In some cases both ends were blown out, and the plates "vandyked" and curled up, the distortion being such as is difficult to describe. These latter effects were due to the flight of the parts and the consequent shock on grounding, and may be considered as secondary, while it is clear, from the direction in which the parts had flown, as well as from the character of the rents themselves, that the primary ones, from which the explosion had sprung, were those at the transverse seams over the furnace.

The Cornish boiler was also rent transversely, at about the middle of its length, both through the shell and flue tube, the end furthest from the furnace being demolished, the shell being opened out, ripped spirally, and the end plate torn off. The other half of the boiler was comparatively uninjured, the whole, though thrown from its original seating, holding together, and the furnace retaining its cylindrical shape.

There is no reason for attributing the explosion either to a deficiency in the number of the fittings, to unwise or excessive pressure, or to

shortness of water, but to the weakness of the transverse seams over the furnace,—to which all externally-fired boilers are found to be liable,—aggravated in the present instance by the use of sedimentary water and the mode of introducing it, by which it was injected directly upon the plates at the bottom of the boiler, and immediately over the fire.

There still remains to be explained the fact of the whole series of five boilers having exploded simultaneously.

The percussive force of water, as an important element in producing the destructive effects in steam boiler explosions, has lately excited considerable attention, and is a subject of much interest. The view is as follows:—The temperature of water in a steam-boiler working at 50 pounds pressure, is 300°, which is 88° above the boiling point at atmospheric pressure. On the occurrence of a rent above the water-line, or the rending off of a steam dome, the blowing-off of the man-hole cover, or the fracture of a steam-pipe, &c., the steam above the surface of the water would escape and remove the pressure from it. The 88° of free heat, with which the whole body of water is charged, over and above that necessary for maintaining it at the boiling point at atmospheric pressure, would instantly flash a considerable portion of it into steam, while the globules, not being generated at the surface merely but throughout the whole mass, would blow up the water with considerable force, converting it into a projectile, having a velocity equal to that due to the pressure. This would give it a destructive force far greater than that of the simple statical pressure of the steam; just as in the injector the stream of water acquires a force of penetration that renders it superior to the pressure of the steam that imparted it, and which enables it to enter a boiler working at a higher pressure than the one supplying the injector. It is thought, by its advocates, that on this principle it is possible that an explosion might happen, without either the existence of any previous weakness of the boiler, the occurrence of any primary rent, or excessive pressure, but simply from the sudden removal of the steam from the surface of the water, when it would be violently projected, as just explained, against the upper part of the shell. It has been proposed to submit this to the test of experiment, and to accomplish the instantaneous clearance of the steam space, either by condensation, effected by the introduction of a jet of cold water, or by the opening of a large valve. Such an investigation would certainly be most interesting and useful, while the result would be highly prized by the engineering world. Of the fact of the sudden liberation of the steam throwing up the water there can be no question, since that is already a matter of experience; whether, however, the entire steam space can be so instantaneously cleared as to allow sufficient velocity of the water being attained—on the accomplishment of which the force of impact depends—appears to me a matter of question, and I cannot but think that steam would be generated with sufficient rapidity on the surface of the water, to retard the velocity of the mass, as well as to form a cushion which would soften the blow against the shell of the boiler. This is a nice point, and must await the issue of the ex-

periment for determination. I have for some time since, in examining exploded boilers, carefully searched for indications of this action, and it appeared at first that there were manifestations of it in the explosion under consideration. For instance, the feed water had been introduced, as previously stated, at the top of the boiler, the feed stop-valve being bolted to the side of the steam dome, and the water carried by the feed-pipe through the steam space. The failure of this feed-pipe would have allowed the water to play amongst the steam, and thus produce the very condensation desired in the proposed experiment just mentioned; added to which, the steam domes were torn off from the shells, as if by upward impact, and blown in a different direction to the boilers themselves. The feed water, however, proved to have been heated by the exhaust steam from the engine, and thus would have produced but tardy condensation; and even if the flight of one boiler, on the rending of the transverse seams over the furnace, had carried away the steam pipe, or rent off the domes of the others, which is highly probable, and thus by suddenly relieving the steam-pressure, set up this percussive action—still, the force of the impact, which must have been upward, can hardly be supposed to have developed the transverse rents previously described, or to have thrown one-half of the boiler to the south and the other to the north. With a full appreciation of the value of the impact theory, it is not thought that it implies in the present instance, as having produced primary rents, important as it may have been in developing secondary ones, but every opportunity will be taken of watching for its manifestation, and communicating the results to the members.

The cause of the simultaneous explosion is thought to have been as follows:—A single externally-fired egg-ended boiler, say No. 3, rent at one of the transverse seams over the furnace in the first instance. The escape of steam and water from the bottom of the boiler then lifted the remaining ones, and threw them up in the air several feet high, blowing down at the same time the brickwork seating, so that the boilers on coming again to the ground, fell upon a loose irregular bed, and all became so strained that each rent and exploded in turn. That the percussive action of the steam was sufficient to have done this, is illustrated by the fact, that one of the cast iron rolls from the mill was lifted by it at the time of the explosion to the height of several feet.

A reference may be of assistance, to a very similar explosion which occurred last year, the particulars being given in the monthly report for March, 1862. In that instance there were four boilers set side by side, and connected together; three of these were egg-ended and externally-fired, while the fourth was a Cornish boiler. The three former were at work and all exploded simultaneously, while the latter, not having steam up, escaped, but had evidently been lifted some considerable height by the explosion of the others, and on its fall rent at the bottom of the shell transversely, and the flue tube was also dislocated at its connexion with the end plate. The fall had made such serious rents in the shell, that had there been any steam in the boiler at the time, an explosion must inevitably followed. This, it is thought, affords

the key to the explanation of the simultaneous explosion of the five boilers under consideration, and which, it is concluded, was due simply to the fracture of a single externally-fired boiler, at the transverse seams over the fire, in the first instance; and to the effect upon the others, of the percussive action of the steam and water escaping therefrom, in the second.

Explosions No. 7 and No. 9 were very similar in character one to the other. Neither of the exploded boilers having been personally examined, only the following scanty particulars have been obtained:—

No. 7 explosion occurred at a colliery to a cylindrical externally-fired boiler, 36 feet long and 5 feet in diameter. This boiler formed one of a series of five, being the second from the engine-house. It was rent by the explosion into four pieces, while the escape of steam and water blew up the boiler seated next to it, which was the centre one of the series, flattening it on one side, reversing it end for end in position, and rolling it over the other boilers, finally depositing it on the ground beyond. It will be seen that the treatment of this boiler, on the rupture of the one alongside of it, corroborates the view given with regard to the cause of the simultaneous explosion of the five boilers referred to above, and it is hoped that fuller particulars may be obtained.

No. 9 explosion occurred at an iron-works, to a cylindrical externally-fired boiler, about 35 feet long and 5 feet diameter, which was the outer boiler of a series of five.

It will be observed that the seven boilers which have exploded during the month have all been of the egg-ended, externally-fired class, with the solitary exception of the Cornish one, which suffered only through the explosion of the others; and it is trusted that the fact of the constantly recurring failure of these externally-fired boilers will at length dispel the false estimate so generally entertained of their safety. The proprietor of the iron-works at which No. 8 explosion occurred, at once adopted the wisest course, and resolved upon having no more of the externally-fired class upon his works, but laying down "Lancashire" boilers in their place; experience having shown him that the plates over a furnace of an internally-fired boiler may fail without moving it off its seat, or causing any loss of life; while with an egg-ended boiler its entire rupture and the flight of the parts, as in No. 7 explosion, is the result.

In another case one of our members, employing several of these externally-fired boilers, has found them to crack at the transverse seams, without warning, for a length of two feet, and consequently determined, as in the previous instance, to condemn them altogether; while to prevent rupture in the meantime, before they can be replaced, contemplates lashing the two ends together with strong longitudinal stays, so as to prevent their flying apart should failure at the transverse seams occur.

On the Behavior of Chloride, Bromide, and Iodide of Silver in Light, and the Theory of Photography. By HERMAN VOGEL.

From the London Chemical News, Nos. 206, and 208.

(Continued from page 127.)

The next question entered upon by the author is that of the influence which foreign matters exert on the changes which chloride, iodide, and bromide of silver undergo in the light. Water appears to have no influence on the action of light. In the case of chloride of silver, acetic and dilute sulphuric acid seemed to exert no influence on the changes of color, but nitric acid appeared to delay the coloration. AgCl placed in yellow fuming NO_5 colored slowly, partly in consequence, the author supposes, of some absorption of the chemical rays. Fuming SO_3 completely prevented the coloration; after a week's exposure the AgCl remained perfectly white. AgCl is slightly soluble in fuming SO_3, and forms with it a compound insensible to light. HCl prevents the coloration of AgCl, perhaps in consequence of the formation of a compound on which light has no action. A solution of sulphate of iron also hindered the coloration of AgCl by absorbing the greater part of the chemical rays.

The influence of dilute acids on the coloration of bromide of silver is insignificant. That exposed under nitric acid was much less colored than that exposed for the same time under water. On boiling colored AgBr in NO_5, sp. gr. 1·2, the grey violet mass changed to a uniform yellow grey, but no silver was dissolved.

The influence of acids on the changes of $AgI\beta$ are the most striking. Five glasses were simultaneously exposed containing $AgI\beta$ with nitric acid (sp. gr. 1·2), sulphuric acid ($_1HO,5SO_3$), acetic acid, nitric acid, and water. After a few minutes the differences in color were remarkable. The iodide under water appeared of a deeper grey than that under the acids; but that under nitric acid, was still yellow. After an hour's exposure that under the NO_5 still appeared a pure yellow, under SO_3 it was somewhat grey, under acetic and citric acids of a darker shade, but that under water was darkest. After a day's exposure the iodide under NO_5 also became grey.

When NO_5 is poured upon grey AgI, the iodide is quickly restored to its original yellow color, but no silver is dissolved; but some decomposition takes place on long standing. SO_3 also exerts a slight bleaching power.

$AgI\beta$ exposed under a solution of KI did not change in the least. When a solution of KI on grey-colored AgI, the latter turned yellow immediately. In the former experiment iodine was set free in consequence of the decomposition of some KI. The author proved that a solution of KI in water is quickly decomposed on exposure. Paper soaked in solution of KI, and exposed under a negative, gave a yellow picture on a white ground, the former turning blue when a dilute starch solution was applied.

The author comes next to the *influence of nitrate of silver*. In the case of *chloride of silver* exposed in a solution of one part $AgONO_5$ to five parts HO, the action of light seemed to be a little accelerated.

When bromide of silver was exposed with the solution of nitrate it became intensely colored in a few minutes. In diffused light the change was remarkable; but when exposed to direct sunlight the AgBr in a few minutes became of a dark blackish grey with a shade of violet. AgI under the same circumstances, was colored in a few minutes of deep grey with a greenish shade. This deep coloration took place when a dilute solution of $AgONO_5$ was employed. When AgBr and AgI were both exposed together in a solution of $AgONO_5$, the AgBr became more deeply colored than the AgI.

To account for these appearances, the author first exposed simple solutions of nitrate of silver, and satisfied himself that even when pure water was employed some decomposition took place, and silver was separated. He believes that the nitrate of silver is first reduced to the state of suboxide, which is acted on by the free nitric acid and further reduced to metallic silver. It was found that AgBr exposed in the nitrate solution showed the presence of free silver, and the author infers that the reduction of nitrate promotes the reduction of the bromide, and believes the darker coloration to be the consequence of this double action.

In chloride of silver exposed in solution of nitrate the author found that a separation of silver took place.

In the case of AgI exposed in a solution of $AgONO_5$ the author also believes that some reduction takes place. A solution of $NaOS_2O_2$ poured on iodide so exposed leaves behind a small quantity of greyish-black granules, which may be separated by long washing and decantation. They dissolve in NO_5 and the solution gives a precipitate with HCl.

Schnauss ascribes the intense coloration which takes place with AgI under the nitrate to the formation of a compound of $AgI+AgONO_5$, which is peculiarly sensible to light. He found that on boiling AgI in a concentrated solution of the nitrate, silky crystals were deposited, which very quickly blackened in the light. Sutton and Schnauss both suppose the sensibility of AgI to depend upon the presence of a trace of nitrate which cannot be removed by washing. The author himself regards the heightened sensibility of AgI in contact with $AgONO_5$ as the result of a simple contact action. He denies that a trace of nitrate has the effect ascribed to it, and quotes the following experiments to support his position :—

He took paper prepared with $AgI\beta$, and after well washing, left it for five minutes in a solution of common salt (five per cent.). If any trace of nitrate had remained it would then have been converted into chloride. The paper was then again well washed, and afterwards exposed. It behaved in exactly the same way as paper not treated with common salt.

The author then gives the following *resumé* of the results he obtained in his experiments :—

1. Chloride of silver, whether prepared with an excess of silver salt or with excess of HCl or NaCl, is decomposed in the light, becoming colored violet, not black; chlorine being set free, and a subchloride left behind.

2. This decomposition takes place when all moisture is excluded, and under English SO_3 and NO_5.

3. HCl and fuming SO_3 completely prevent the decomposition; English SO_3 and NO_5 only delay it.

4. Sulphate of iron solution also delays the action by absorbing some of the chemcal rays.

5. A solution of $AgONO_5$ hastens a little the coloration of AgCl by light. In this case free silver instead of a subchloride is formed in consequence of the decomposition of the nitrate.

6. Bromide of silver, whether prepared with an excess of silver salt, or of KBr solution, is colored a pale grey violet in the light, giving bromine and leaving a subbromide of silver.

7. This subbromide decomposes in NH_3, giving metallic silver and a solution of AgBr.

8. Nitric acid delays the action of light on AgBr more than on AgCl.

9. By heating the colored AgBr with NO_5 the color is changed to a yellow grey, and no silver is dissolved.

10. Nitrate of silver solution greatly hastens the action of light on AgBr, and in this case not only a subbromide but metallic silver also is produced.

11. AgCl precipitated from an excess of silver solution decomposes sooner in the light than AgBr precipitated under like conditions. AgCl precipitated in excess of NaCl solution, on the contrary, decomposes more slowly than AgBr precipitated by an excess of NaBr.

12. AgI precipitated by an excess of KI solution is not in the least affected by light.

13. AgI precipitated in an excess of silver solution becomes colored a pale grey in the light. No iodine is set free, and any chemical decomposition is in the highest degree improbable.

14. Acids, even diluted, delay the coloration of AgI in the light.

15. Nitric acid, specific gravity 1·2, restores the yellow of darkened iodide, but no silver is dissolved.

16. KI solution instantly turns the deep yellow AgI precipitated in an excess of silver salt to a pale yellow and destroys its sensibility; it also turns the grey colored iodide to a pale yellow.

17. $AgONO_5$ greatly promotes the action of light on AgI.

18. Of the three salts AgCl, AgBr, AgI, when exposed in contact with $AgONO_5$, AgBr becomes most, and AgCl the least colored.

19. Pure solid $AgONO_5$ does not decompose in the light, but a small quantity of silver separates from a solution in the form of small black granules.

20. Solid KI does not decompose in the light, but free iodine is soon separated on the exposure of a solution.

The author next occupies himself with the changes which are produced in the developing process.

What are *the changes produced in the developing process?*

The author starts with a review of the various opinions advanced by Schnauss, Sutton, Hardwich, Monckhoven, Devanne, and others. This we omit, and proceed with the original experiments here detailed.

In the first place he prepared a number of papers, by floating them first on the solutions of iodide of potassium, bromide of potassium, and chloride of sodium, and afterwards on a solution of nitrate of silver containing 8 per cent. of $AgONO_5$. These were well washed and then dried.

The AgCl paper was quite white, the AgBr pale yellow, the AgI dark yellow. Papers so prepared were carefully preserved from the light for some weeks, during which time they were but very slightly colored.

The developer employed was a solution of one gramme of pyrogallic acid, and one gramme of citric acid in 250 grammes of water. Four drops of a 5 per cent. nitrate of silver solution were added to five cubic centimetres of the foregoing solution. The object of the citric acid was to delay the reduction of the silver salt by the pyrogallic acid.

When pure pyrogallic acid is mixed with a silver solution a precipitate is almost immediately produced of granular, pulverulent silver, mixed with a black substance, which may be extracted by means of ammonia. Such a precipitate is obtained on the unexposed as well as the exposed parts of the paper; but when an acid is employed the precipitate appears more slowly, and first on the exposed part, and only later when the decomposition has proceeded to the end does the unexposed part become faintly colored. It is easy to remove the developer before the coloration of the unexposed part takes place.

First experiment. Strips of the chloride, iodide, and bromide of silver paper, prepared as described, and also a strip dipped only in solution of $AgONO_5$ and afterwards washed, were exposed to diffused daylight for one minute, half of the paper being covered. The exposed part of the AgI paper was colored pale grey, the AgBr pale grey violet, the AgCl pale violet.

The developer before mentioned was poured over the papers simultaneously. The exposed parts presently became darker, the AgI soonest, then the AgBr, last the AgCl. The coloration gradually deepened, and in the end the AgI became of a deep black grey, the AgBr a clear brownish grey, and the AgCl a pure brownish yellow shade.

The paper prepared with nitrate of silver only was but faintly colored on the exposed part, but left in the air for some minutes it became brownish, a proof that a trace of silver was left after the washing.

2. The same experiment was repeated, but in place of the developer before mentioned, a solution of pyrogallic acid *without any silver solution*, was poured over the papers. By this the papers were *not colored* even after a minute.

From these experiments it results:—

1. That pyrogallic acid *alone* does *not* effect any change in exposed AgI, AgBr, and AgCl paper.

2. That the haloid salts of silver in the nascent state possess the property of attracting and fixing the separated granular and pulverulent silver.

3. That paper soaked in silver solution only, and even after long washing, retains a trace of silver, and browns in the light, behaving with the developer just like AgCl, AgBr, AgI, paper.

The author afterwards repeated his experiments with papers prepared according to Bunsen and Roscoe's method by complete immersion in the solutions, and ascertained that of the three silver salts, after exposure to light under perfectly similar circumstances, the AgI is most deeply colored by the developer, and the AgCl the least This is remarkable, inasmuch as AgCl is the salt which is most deeply colored by light alone, and undergoes the greatest chemical change; while, on the contrary, AgI undergoes the least visible alteration in the light, and probably suffers no chemical change. It follows that the change occasioned by light, which renders these capable of attracting silver particles, is not parallel with the chemical changes, and, indeed, may be different from them.

For this reason we must assume another action of sun-light besides the chemical. This action, which fits iodide of silver and other bodies to attract and fix particles of silver the author calls the *graphic action.*

The capability of certain bodies after exposure to attract the silver particles (and also mercury particles as in Daguerre's process) he calls the *photographic sensibility.*

The dark coloration which they assume under the developer, the *photographic coloration.*

In opposition to these the author places the *chemical action*, that is, the disposition to chemical decomposition, or composition conferred by light:—

The *photo-chemical sensibility*, that is, the capability of certain compounds of undergoing decomposition in sunlight, and

The *photo-chemical coloration*, that is, the color changes that they suffer.

Thus, we may say, that iodide of silver possesses the most photographic sensibility, chloride of silver the least, while bromide of silver stands between the two.

The author then proceeds to describe the *photographic* behavior of the silver haloids in the presence of other bodies.

1. *Influence of Water*—AgCl, AgBr, and AgI papers, half of each being wetted with distilled water, were exposed, while still moist, for a minute, and afterwards the developer was poured over. The dry and the moist parts behaved photographically almost alike.

2. *Influence of Acids.*—We may sum up this by saying, that from the author's experiments it follows that *acids weaken or destroy the photographic sensibility.* Papers moistened with nitric acid *after exposure* were quite indifferent to the action of the developer, while the part not moistened darkened, showing that the acid had destroyed the impression of the light. Dilute sulphuric and acetic acids delay and weaken the action of the developer.

3. *Influence of Iodide of Potassium*—AgI paper moistened with a fresh solution of KI was insensible to light, and also to the developer

and paper moistened after exposure did not become colored by the developer; hence the author concludes that KI perfectly destroys the photographic sensibility of AgI both during and after the exposure.

The Effect of Fire on Cast Iron.

From the London Builder, No. 1075.

Attention has been directed by Dr. Percy, to the fact that several of the cast iron girders at the German Bazaar, were much bent, and the columns distorted, by the operation of the fire which occurred there some weeks ago. The subject is one of great importance with reference to the use of cast iron for building purposes. The girders in question were 18 feet long and 13 inches deep in the middle, tapering off slightly towards each end, and flanged, as usual, at the bottom. Of those entire after having fallen to the ground two were bent laterally in a striking and a nearly equal degree. The flexure was gradual from end to end. The deviation from a straight line at the end was 22 inches. No cracks could be anywhere detected. Many of the cast iron columns, which are still upright, Dr. Percy says, have been singularly twisted at the upper part, as though the metal there had been softened by heat, and had yielded without cracking, to the effect of pressure from above. As far as he could judge, there was no very decided evidence of fracture in either girders or columns from the injection of water upon them; and yet, from the fused glass and other objects which lay scattered about, it was certain that they must have been exposed to a pretty high temperature.

We may endorse Dr. Percy's observation, that a museum of objects in illustration of accidents, such as the bursting of boilers, breakage of railway axles and tires, railway collision, &c., would be as interesting as it would assuredly be important in a practical point of view.

New Process for Silvering Glass. By M. A. Martin.

From the London Artizan, Oct., 1863.

Among the large number of processes for silvering, Drayton's process is the best adapted for telescope glasses; but, as this process requires great skill on the part of the operator, I have endeavored to find some method, which, by its simplicity and sureness, might become general. After carefully studying and experimenting on all the known processes (aldehyde, sugar of milk, glucosate of lime, &c.), I have arrived at one, which, from its simplicity and the firm adherence of the layer of silver deposited, seems to fulfil all the necessary conditions. I begin by preparing:—1. A solution of 10 grammes of nitrate of silver in 100 grammes of distilled water. 2. An aqueous solution of pure ammonia, marking 13 degrees on Carter's areometer. 3. A solution of 20 grammes of pure caustic soda in 500 grammes of distilled water. 4. A solution of 25 grammes of ordinary white sugar in 200 grammes of distilled water. Into this pour 1 centimetre cube of nitric acid at 36 degrees, boil for twenty minutes, to produce the

interversion of the sugar, and then make up the volume of 500 centimetres cube with distilled water, and 50 centimetres of alcohol at 36 degrees. This done, I prepare an argentiferous liquid by pouring into a flask 12 cubic centimetres of the solution of nitrate of silver (1), then 8 cubic centimetres of ammonia at 13 degrees (2), then 20 centimetres of the solution of soda (3); and lastly, make up a volume of 100 centimetres by 60 centimetres of distilled water. If the proportions have been properly observed the liquid will remain limpid, and a drop of solution of nitrate of silver will produce a permanent precipitate; then after being left quiet for twenty-four hours the solution is ready for use. Clean the surface to be silvered with a cotton plug impregnated with a few drops of nitric acid, then wash it with distilled water, drain and place it on supports on the surface of a bath, composed of the argentiferous liquid, to which has been added one-tenth or one-twelfth of the solution of sugar (4). Under the influence of diffused light the liquid becomes yellow, then brown, and after from two to five minutes the whole of the surface of the glass will be silvered; after ten or fifteen minutes it will have attained the required thickness; it must be washed first with ordinary water, then with distilled water, and stood upon its edge to dry in the air. The surface will then be covered with a light, whitish veil, easily removed by a little polishing rouge on chamois leather, leaving a brilliant surface perfectly adapted by its physical constitution for the purposes for which it is intended.

Railway Grease.

From the Chemical News, No. 207.

The process of manufacture is exceedingly simple. The fats are melted in a boiler, and brought up to 130° to 190° F. The water and soda crystals are heated in another vessel to 200° F., and both run into a wooden tub, with constant stirring, which is continued at intervals until the mixture is cold. Slow cooling insures a firm article, and large batches, which retain their heat for a considerable time, are therefore preferable. Care is taken for obvious reasons to avoid the introduction of sand or gritty matter. The proportions of materials vary in different establishments, and in the same establishments at different seasons of the year, the grease for July use being too firm for December, and *vice versa*. 25 per cent. is the lowest quantity of fat that can be safely used in the coldest weather, while 25 per cent. is amply sufficient for our warmest summer use. The following proportions have been used with excellent results:—

	Winter.			Summer.		
	cwt.	qr.	lb.	cwt.	qr.	lb.
Tallow . .	3	3	0	4	2	0
Palm oil . .	2	2	0	2	2	0
Sperm oil . .	0	1	7	0	0	27
Soda crystals .	1	0	14	1	0	8
Water . .	12	3	12	12	0	26

These proportions produced one ton of grease (allowing 2½ per cent.

for loss). That marked "summer" ran 1200 miles. The sperm oil, although small in quantity, has an excellent effect; but some makers, for economy, use rosin oil instead, although the result is questionable. —*Chemical Techology, by Richardson and Watts.*

Electro-Magnetic Phonograph.

From the Journal of the Society of Arts, No. 569.

This machine is capable of being attached to piano-fortes, organs, and other keyed musical instruments, by means of which they are rendered melographic, that is, capable of writing down any music that is played upon them.

So keenly have musicians at all times felt the extreme tediousness of writing music by hand, and the impossibility of preserving the most valuable impromptu pieces in their full and flowing beauty, that immediately on the introduction of the piano-forte into England strenuous efforts were made by men of inventive skill to supply the instrument with the means of registering the music performed upon it. "The first piano-forte seen in England was made by one Father Wood, an English monk at Rome, and by him sold to Samuel Crisp, Esq., who sold it again to Fulke Greville, Esq., for one hundred guineas."* This was about 1757.

The Rev.—Creed would appear to have been one of the first, if not the first, to think of constructing a melographic instrument, and in the year 1747 he sent to the Royal Society a paper, entitled "A demonstration of the possibility of making a machine that will write extempore voluntaries, or other pieces of music, &c."†

There are also obscure accounts of a machine made in 1770, by a monk named Engramelle.

In a German work of 1774, John Fredrick Unger, a counsellor of justice at Berlin, claims priority of invention against Mr. Creed, though it seems most probable that each made a similar invention unknown to the other.

There is no doubt whatever that the Académie of Berlin was presented by Hohlfield—an ingenious mechanic who received some suggestions from Euler—with a machine which, to a limited extent, answered its purpose. It consisted of two cylinders moving paper between them, on which, by means of a crayon, each key made a mark when pressed down in the act of playing. But not only was the action of playing very fatiguing, but the music must have been of a most inconvenient width—that of the key-board—and without any stave, accidentals, &c.; in fact, a mere series of dots showing such and such keys were pressed down in the course of the performance, but utterly failing to mark the time, key, or accidentals. The Académie, however, in consideration of the great ingenuity of the contrivance, rewarded the inventor with a handsome gratuity.

* Riambault's History of the "Piano-Forte."
† Phil. Trans. vol. xliv., p. 445.

In 1827, M. Carreyre made trial, before the Committee of the Fine Arts of the Institute of France, of a melographic piano, which consisted of a clockwork movement, which unwound from one cylinder to another a thin plate of lead, on which were impressed, by the action of the keys of the instrument, certain peculiar signs, which might be translated into the ordinary notation by means of an explanatory table.

"After the experiment, the plate of lead was removed, to make the translation, and a commission was appointed to report; but as no report was ever made, it is probable that the translation was not found to be exact. At the same time M. Baudouin read before the Institute a paper accompanying it with drawings, concerning another melographic piano; upon the merit of which we do not find that the Institute pronounced.*

These accounts prove two important facts; the great efforts made and the small success achieved—this want of success proceeded from the lack of a proper motive power, none having used electro-magnetism—for it must be evident to all acquainted with music that these were as yet nothing more than partially successful experiments, and produced no further result than stimulating inventors to continued exertions.

The causes of failure were many, the most serious being the oversight of endeavoring to derive the mechanical power from the keys of the piano, whereas some power, which, while depending upon the action of the key for its liberation and manifestation, should at the same time exert its force without strain upon the key, still remained a desideratum. Such a power is electro-magnetism, as the mere motion of a piano key, without any alteration in the touch required—may be made to call forth a force of any magnitude required. Now, in Unger's machine the power was derived from the keys alone, and by direct action, thus rendering the touch of the piano so heavy that no one could perform properly upon it. For this reason it is unnecessary to consider further its defects. M. Carreyre's, besides being equally objectionable on the score of its unavoidably heavy touch, and arbitary and unmeaning signs, produced at the best, but an indented sheet of lead, a medium for writing music on most inconvenient and unmanageable.

A machine which should register in plain black and white on common paper the music performed, giving the score on the ordinary stave, using the flat, sharp, and natural signs, as in all modern music, accurately registering time, bars, legato and staccato, 8va, alto, and basso passages, and adapted to all keys, still remained a desideratum, for from 1827 to 1863 no further progress was made, though many continued to give their attention to the subject.

But in 1863 Mr. Fenby applied electro-magnetism, and a machine was patented by him, January 13th, in that year, which, without altering the touch or appearance of an ordinary piano, is stated to be capable of registering the most complicated music.

Before giving any detailed description of the construction and capa-

*Riambault.

bilities of the phonograph, it may be well to point out the obstacles to be overcome in the notation, and thus to separate the possible from the impossible.

The most obvious difficulty—and one which if not overcome would render all other excellencies nearly, if not quite, futile—is the means of marking the various durations of the notes from the breve to the demisemiquaver, &c. This was a difficulty, inasmuch as the ordinary open, closed, and tailed notes cannot possibly be rendered available in an instrument registering that which is performed upon it.

The following considerations will render this apparent. The longest note is practically but the fusion of a number of shorter notes, from which it follows that on any particular key being depressed, as in playing, its first touch would be the shortest note of the notation, and the machine would immediately print such shortest note, and could not afterwards alter it; for to suppose a piece of machine to render shorter or longer notes by arbitrary signs, having but a fictitious relation to their duration,is to suppose its possession of a reasoning power, the absurdity of which needs no comment. From these considerations, and others which will readily occur to the mind of the reader, it is manifest that some system is required in which the duration of sound and the performance of the printing may be co-existent, and thus produce a complete reciprocity of action between the two. In other words, a short note must be capable of becoming a long one in the printing as in the playing.

Bearing these facts in mind will lead to a complete comprehension and appreciation of the system. Each note shows the portion of time occupied in playing it by the length it occupies in the bar, and consists of a horizontal black line proportionate in length to the duration of the note, while the rest of the notation needs no comment, it being in all respects identical with that at present in use.

Having considered the notation, the next thing to which our attention will naturally turn is the mechanical appliances employed to produce this notation. First, then, as to the touch of the piano: this remains, to all intents and purposes, the same as if without the phonograph attached, as the mechanical power is not derived from the motion of the keys, but from a voltaic battery; the only part performed by the key being to bring a small brass stud, on its under side, in contact with a slender spring; this causes an electro-magnet to bring a tracer against the paper which is continually moving at a fixed rate and thus marks the note. When the key is no longer depressed, the tracing ceases, and the rod slides back; this mechanism being capable of registering the slowest or most rapid playing. The accidentals are printed by revolving type, acted on by the same sliding-rod and magnet. The accidentals are adapted for all keys, so that any number of flats or sharps may be correctly registered; the machine being capable of distinguishing accidentals, flats, sharps, and naturals from those which are proper to the key in which the music may be pitched. That is to say, if the key of A natural be used, F, C, and G, when played sharp, will have no sharp sign in the body of the music, whereas if the naturals of these

notes be struck, or the sharps of any others, suitable accidentals will be printed.

Having now reviewed the notes and signs proper to them, the bars will be considered. The barring of the music is performed in a simple manner, precluding the possibility of derangement, and is yet so accurate in adjustment that it correctly follows the accentuation of the most complicated piece of music. When a rallantando movement occurs, the bar or bars through which it runs will be actually lengthened in such a proportion as will accurately denote the character and expression of that part of the music. The same manifest advantages occur in the matter of legato and staccato movements.

The machine requires only blank paper, as it rules the stave and prints the score simultaneously. The inventor furnishes a small battery of convenient and simple form. The charge consists of sulphate of copper and water: one charge lasting for some months. The whole is in a neat drawer at the bottom of the machine, and offers nothing of difficulty or unpleasantness in its management, and requiring to be touched only to supply water to it.

Properties of a new Gun Metal.

From the Lond. Mechanics' Magazine, September, 1863.

Messrs. Deville and Caron have lately been making experiments on the properties of a new gun metal, a compound of silicium and copper. When copper contains rather less than five per cent. of silicium, it presents a fine bronze color, is fusible, and rather harder than bronze, but is perfectly ductile, and can be readily worked without clogging the tools as bronze does. Its tenacity is remarkable, being equal to that of iron. Silicium is the basis of sand, and the manufacture of its compounds with copper may be made by fusing together a mixture of sand, sodium, and copper, with some common salt and fluor spar as flux.

Soluble Silk.

From the Lond. Practical Mechanic's Journal, Oct., 1863.

This, which was the philosopher's stone on the search for which the late Mr. Schwabe of Manchester expended the energies of a life, has apparently at last been found by M. Persoz, the younger, and the *modus operandi* is due to the discovery of *dialysis* by our own Professor Graham, master of the mint. Persoz has found, as we noticed, many months ago, that silk is soluble in solution of chloride of lime, but he had sought in vain for any chemical agent by which the dissolved silk might be separated from its saline solvent. He at length tried dialysis, and by its means, separated the whole of the chloride of zinc, leaving the silk alone in the state of a limpid, colorless, tasteless liquid, which by evaporation or drying produces a gold-colored and *brittle* varnish. It remains still then to get back the silk with all its original physical properties unaltered.

The Production of Cast Steel directly from Pig Iron.

From the Lond. Mechanics' Magazine, Jan., 1864.

None of the foreign papers seem to have noticed the attempts of Cazanave to obtain cast steel directly from pig iron. The idea itself appears to be very ingenious, but of course the question is whether it is applicable in practice. The foundation of this new method is the influence of steam on a thin stream of pig iron. If we take an iron tube of a certain diameter with sides of the necessary strength, form a ring out of it, and fix on its circumference, towards the centre, three or more tubes, we have a tube ring with three or more radii. The radius is made fast to the tubular pipe; the ends of these tubes, which are open, do not quite reach to the centre of the ring, and have, therefore, between the ends an empty space, in which the pig iron is allowed to flow in a stream of a certain strength. The stream led from the boiler into the tubular pipe flows out of the openings of the three tubes, and operates directly upon the pig iron. It is said that the oxygen of the steam oxidizes the carbon of the pig iron, the silicium, a portion of the sulphur, phosphorus, and other impurities in the pig iron; the hydrogen combines with the carbon, sulphur, phosphorus, arsenic, and other bodies, with which it forms combinations of hydrogen. The carbonized and purified metal falls into a crucible or other vessel placed immediately under the apparatus. The metal obtained contains impurities, and must, therefore, be smelted in crucibles in a blast or reverberatory furnace. This is the essential part of the process; the simplicity of the method and the cheapness of the product are evident.

Now arises the questions:—Is it possible to obtain steel in large quantities by this method? will it be of the same quality as the small quantity obtained on trial? and, if it is possible, at what price can it be obtained?

In answer to these questions, Cazanave asserts that by his method steel can be obtained in great quantities, not inferior to the best steel, and proportionately cheaper; for his best quality steel can be obtained for £18 per ton. This is difficult to believe, but the inventor affirms that it is so, and at the same time warrants the excellent quality of his steel. In the present method of obtaining steel, good iron must be used, which is cemented, and the cemented iron, that is the steel, is smelted in crucibles. By Cazanave's method cementation of the iron is avoided, so that the cast steel may be obtained in unlimited qualities. If this new method turns out practicable, it will be possible to work up the whole daily production of a blast-furnace into steel. For this only the apparatus is required, which is not very costly, and which would be erected near the blast furnace and stream of pig iron. The stream would be divided into rays of the necessary strength, and each one directed into an apparatus. By Bessemer's process about ten tons of steel are obtained per day at Sheffield; while by Cazanave's method sixy and seventy tons per day could be obtained, and a blast furnace is being erected at Charleroi which will produce about seventy-

four tons per day. The samples of steel furnished by this new process are reported to be very good. They were obtained from pig iron smelted with coke, but it is supposed that charcoal pig iron would give better results.—*Colliery Guardian.*

For the Journal of the Franklin Institute.

Valve Motion.—Cut-offs.

Mayer's, or as its modification is called in this country, Merrick's Valve.

By JOHN D. VAN BUREN, JR., C.E., 2d Asst. Eng. U.S.N.

The object sought in this paper is to obtain formulæ for designing the parts, and to discuss the circumstances of the motion, of this valve. This valve is a momentarily adjustable *Cut-off*. Fig. 1, shows an outline of a longitudinal section of the valve and its eccentrics. SS is the valve-seat; PP, are the ports leading to the cylinder AA, E its exhaust passage; *pp*, *steam* ports of the main valve VV, and *e* its exhaust-port. *ll* are two small slides driven by an independent eccentric over the back of the main valve, and adjustable upon the stem by means of right and left hand screws and nuts; so that by turning the stem the valves can be made to approach or recede from each other, according to the degree of *expansion* required. C is the shaft with eccentrics attached. To simplify the sketch the steam-chest, &c., are omitted. The action of the valve will be readily understood by reference to the figure. The steam can enter the cylinder only through the ports *pp*, and, by adjusting the valves *ll*, these ports can be closed at almost any point of the motion of the piston AA. It will be seen that the main valve is simply a modification of the ordinary three-ported locomotive slide. The valves *ll* are usually *roofed* over, and this roof or back connected with the condenser by means of a pipe and ring packing against the steam-chest bonnet, thus making the valve a *balanced* valve.

The following notation will be adopted in this discussion:

R=length of crank of shaft.

r_1=crank-arm or half throw of eccentric of main valve.

r=crank-arm or half throw of eccentric of cut-off valves *ll*.

c=cover or *lap* of main valve.

l=lead of main valve.

d=distance between outer edges of ports *p* and valves *l* when the main valve is in its *central* position.

v=length of faces of cut-off valves *ll*.

p=breadth of steam ports *pp*.

b=distance between *inner* edges of ports *pp*.

x=angle made by crank R with axis of cylinder, at the instant when steam is cut off.

θ=angle made by r_1 at same time, with same line.

Main Valve for Central Position. *Fig. 1.*

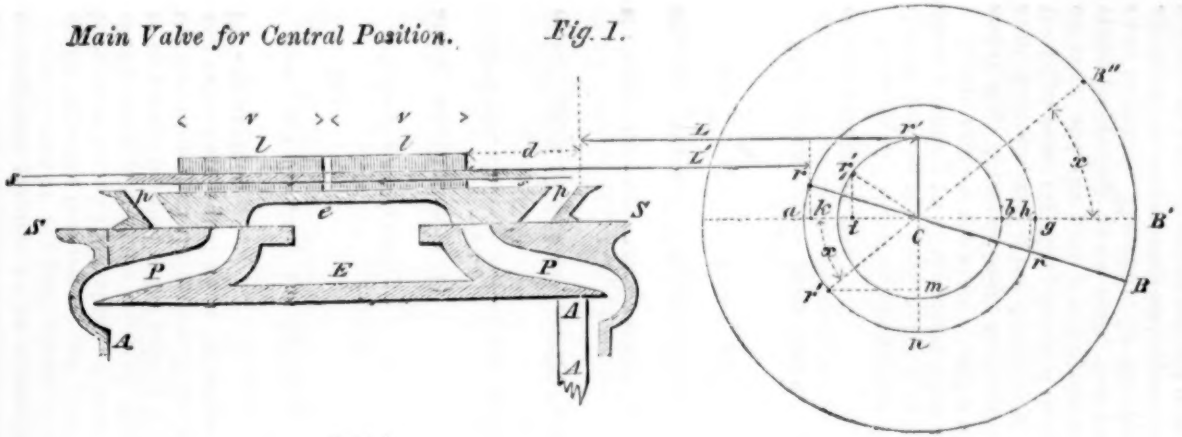


FIG. 1.

Angle $rCa = \sin.^{-1}\frac{c+l}{r_1}$

$kh = 2r \cos. \sin.^{-1}\frac{c+l}{r_1}$

Angle $bCr'_1 = 90° + \sin.^{-1}\frac{c+l}{r_1} + x$

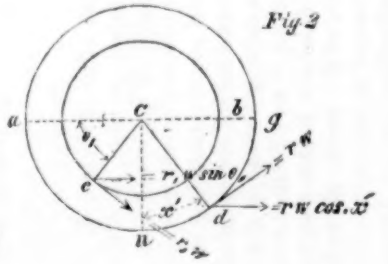
$Ci = -r_1 \cos. \theta$

$r'm = r \cos. x$

When edges of valves come together $L + Ci = L' + mr'$
When main valve is in central position $L + d = L' + Ck$ } Eq.(1)&(1′)

N. B.—All angles measured round from CB′.

Fig 2



Suppose now the crank is at B', or the piston at the top of its stroke. By following out the motion, it will be perceived, that to make the arrangement effective as an adjustable *cut-off*, the eccentric of the valves *ll* must be set 180° ahead of the crank R, provided no rock-shafts intervene between rr_1 and their respective valves. The eccentrics must be set 180° ahead of their proper position without rock-shafts, when rock-shafts are used. Let the eccentric rods be supposed to be always parallel to the axis of the cylinder. Then observing that the distances from the centre of the shaft to the edges of the port p and valve l are equal when the edges come together, we shall have for any angle x.

$$\text{L}-r_1 \cos\ \theta = \text{L}-r_1 \cos.(90°+\sin \frac{^{-1}c+l}{r_1}{}^{*}+x) = \text{L}'+r\cos.\ x \quad (1)$$

But

$$\text{L}+d = \text{L}'+r\cos.\sin.\frac{^{-1}c+l}{r_1}{}^{*} \quad . \quad . \quad . \quad . \quad . \quad (1)'$$

and by substitution in (1)

$$d = r\cos.\sin.\frac{^{-1}c+l}{r_1} - r_1\cos.(90°+\sin.\frac{^{-1}c+l}{r_1}+x) - r\cos x \quad (a)$$

$$\text{or,} = \frac{r}{r_1}\sqrt{r_1{}^2-(c+l)^2} - r_1\cos.(90°+\sin.\frac{^{-1}c+l}{r_1}+x) - r\cos.\ x \quad (2)$$

since $\sin.\sin.\frac{^{-1}c+l}{r^1} = \frac{c+l}{r_1}$, and $\cos. = \sqrt{1-\sin.^2}$

or, since $-\cos.(90°+a) = +\sin a$.

$$d = \frac{r}{r_1}\sqrt{r_1{}^2-(c+l)^2} + r_1\sin.(\sin.\frac{^{-1}c+l}{r_1}{}^{\dagger}+x) - r\cos.\ x. \quad (2)'$$

The arc $\sin.\frac{^{-1}c+l}{r_1}$ being that through which r_1 must move from its central position to give $c+l$.

Formula (2)' therefore shows how far the edge of l must be from that of p when the main valve is in its central position, in order to cause a cutting off of the steam when the angle of the crank is x.

Again, suppose the arms r_1 and r to have moved to the positions c and d, Fig. 2, respectively; both valves will now be traveling in the same direction, and if the velocities of the two valves are *equal* when the edges come together, then will the main valve get ahead of the cut-off valve, and the port p will *again* be opened if any further motion ensue (supposing, as we must, that l was *behind* p before the edges came together). Therefore, for that position of the crank, above *half-stroke*, which corresponds with *equal* velocities of the two valves, ll are useless, and for all points beyond to the end of the stroke. The main valve must therefore be provided with sufficient *lap* to cut off the

* Sin ^{-1}x means the arc or angle whose *sine is equal to* x, and similarly for $\cos^{-1}$.

† L and L' are the lengths of the eccentric-rods of r_1 and r respectively.

steam when the crank assumes this limiting position, and in practice the lap should be slightly greater than this amount.

To find this limiting position, refer to fig. 2, and let w be the angular velocity of the shaft, then by the conditions,

$$r_1 w \sin.\theta_1 = r w \cos. x^1 \quad . \quad . \quad . \quad . \quad (3)$$

But $\theta_1 = x - \left(90° - \sin.\frac{-^1c+l}{r_1}\right) = x + \sin.\frac{-^1c+l}{r_1} - 90°$

and $x^1 = x - 90°$.

$$\therefore -r_1 \cos.\left(x + \sin.\frac{-^1c+l}{r_1}\right) = r \sin. x.$$

and since $\cos.(a+b) = \cos. a, \cos. b - \sin. a, \sin. b$, generally.

$$\therefore -r_1 \cos. x \frac{\sqrt{r_1^2 - (c+l)^2}}{r_1} + r_1 \sin x. \frac{c+l}{r_1} = r \sin x.$$

$$\therefore \tan. x = \frac{\sqrt{r_1^2 - (c+l)^2}}{(c+l) - r}. \quad . \quad . \quad . \quad . \quad (4)$$

Therefore the main valve must have sufficient *lap* to cut off the steam when the crank makes an angle x, whose tangent $= \frac{\sqrt{r_1^2 - (c+l)^2}}{(c+l) - r}$ with the axis of cylinder. The positive sign must be used for the radical, and the tangent will then be *negative*, showing the angle to be over 90°.

To find how much is necessary to accomplish this end, we have (see *Bourne's Treatise, Slide-valve*),

$$c = r_1 \sqrt{\frac{2R - s''}{2R}} - \tfrac{1}{2} l \quad . \quad . \quad . \quad . \quad (5)$$

where s'' is the distance of the piston from the end of the stroke when the steam is cut-off.

$$\therefore s'' = R(1 - \cos. x).$$

$$\therefore c = \text{lap} = r_1 \sqrt{\frac{1+\cos. x}{2}} - \tfrac{1}{2} l \quad . \quad . \quad . \quad (6)$$

and we must assume such a value to x in equation (6) that when c calculated by (6) is substituted in (4), the value of x found by (4) shall be *slightly greater* than the *assumed* value of x. This angle x is generally about 120°, and therefore one trial will generally fix how much lap (c) must be given in order that the *main valve* shall cut off before the cut-off valves begin to *uncover* the ports pp.

This maximum value of x substituted in equation (2) will give the maximum value of d required, and will therefore determine the length of the screw on the stem ss; and if $x = 0$, in equation (a), the value of d then obtained will be the proper distance between the edges of p and l, when the main valve is in its *central* position, necessary to cause the

steam to be cut-off when the piston is at the top of its stroke. A value $x = -\sin.\frac{-^1c+l}{r_1}$, will give equation (a) $d=0$, as it should.

To prevent the *uncovering* of the *ports pp* at the *inner* edges, the faces of the valves *ll* must have a length corresponding with the maximum separation of the edges *after* steam has been cut off, *i. e. l* must equal the breadth of the port *p* plus the distance which the outer edge of *l* passes *over* the outer edge of *p*, when this distance is a maximum. Now suppose the steam cut off when $x=0$; it will be seen that the maximum value of *d* is the maximum distance to which the outer edge of *l* will attain beyond *p* and therefore,

Breadth of face $= v = d+p$ . . . . . (7)

where *d* has its maximum value.

There however must be a corresponding distance between the inner edges of the ports *pp* to accommodate all these conditions. Let *a* represent the distance between inner edges of valves *ll*, and suppose the main valve to be in its central position; then, we shall have

$$2v+a+d=2r\ \text{cos. sin.}\ \frac{-^1c+l}{r_1}+b+2p-d. \quad . \quad . \quad (8)$$

Since for the *other end of the stroke* the outer edges of the other cut-off valve and port *p*, must be in the same relative position as the two under discussion.

$$\therefore b=2(v+d)-2\,r\cos.\ \text{sin.}\ \frac{-^1c+l}{r_1}-2p+a. \quad . \quad (9)$$

but we may make $a=0$, when the valves are adjusted for a maximum value of *x*; also $v=d+p$, and r cos. sin. $\frac{-^1c+l}{r_1} = \frac{r}{r_1}\sqrt{r_1^2-(c+l)^2}$

$$r\therefore b=4d-\frac{2r}{r_1}\sqrt{r_1^2-(c+l)^2} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where *d* has its maximum value, determined by the value of *x* in equation (4). Observe equation (8) that the valves *ll* travel $2r$ cos. sin. $\frac{-^1c+l}{r_1}$, while the main valve passes from its central position around 180°.

Recapitulation.

$$d=\frac{r}{r_1}\sqrt{r_1^2-(c+l)^2}+r,\ \text{sin.}\left(\text{sin.}\ \frac{-^1c+l}{r_1}+x\right)-r\ \text{cos.}\ x. \quad (11)$$

$$\left\{\begin{array}{ll} & \tan. x=\sqrt{\frac{r_1^2-(c+l)^2}{(c+l)-r}}. \quad . \quad . \quad . \quad . \quad (12) \\ & c=r_1\sqrt{\frac{1+\text{cos.}\ x}{2}}-\tfrac{1}{2}l. \quad . \quad . \quad . \quad . \quad (13) \end{array}\right.$$

$$v=d+p \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$b=4d-2\,\frac{r}{r_1}\sqrt{r_1^2-(c+l)^2}. \quad . \quad . \quad . \quad . \quad (15)$$

The main valve is designed in the same manner as the common locomotive slide. It will be observed that r_1 must *at least* be equal to $dc+p$, in order that the port may be fully opened; and therefore $r_1=c+p$ determines r_1. The *lead* is assumed, according to the judgment of the designer, but generally varies from $\frac{1}{16}$ inch to $\frac{3}{8}$ inch, for engines with high velocities the *lead* being greater than is required for engines with low velocities. This lead will of course depend somewhat upon the *length* of the port p and the capacity of the cylinder, but may safely be assumed between the above limits. If $r_1=r$ the formulæ will be somewhat simplified.

Example.

Let $r_1=5''$, $r=5{\cdot}5''$, $l=0{\cdot}2''$.

Now assume that the cut-off valves are efficient only up to a value of $x=120°$, or for $\frac{3}{4}$ths the stroke of piston; therefore equation (13).

$$c=5\sqrt{\frac{1+\cos.\ 120°}{2}}-\tfrac{1}{2}l=5\sqrt{\frac{1-\frac{1}{2}}{2}}-0{\cdot}1''=\tfrac{5}{2}''-0{\cdot}1=2{\cdot}4''$$

substituting this value of c in equation (12),

$$\therefore \text{ tan. } x=\frac{\sqrt{25-2{\cdot}6^2}}{2{\cdot}6-5{\cdot}5}=-\frac{\sqrt{18{\cdot}24}}{2{\cdot}9}=-1{\cdot}4727=\text{tan. } 124°\ 11'$$

or by logarithms

$$\text{log. tan. } x=\text{log.}-\sqrt{\frac{18{\cdot}24}{2{\cdot}9}}=-0{\cdot}1681144=\text{log. tan. } 124°\ 11''$$

Therefore this value of c is sufficient, and the main valves will cut off the steam before the limiting angle for ll is attained—being 4°11′ before the edges of the valve l comes in contact with p, the steam-port of vv; d need not therefore be calculated for an angle greater than 120°.

$$\therefore \text{ (eq. 11) } d=\frac{5{\cdot}5}{5}\times\sqrt{25-2{\cdot}6^2}+5\text{ sin.}\left(120°+\text{sin.}\frac{-'2{\cdot}6}{5}\right)+5{\cdot}5\times\tfrac{1}{2}$$

$$d=1{\cdot}1\sqrt{18{\cdot}24}+5\text{ sin. }(120°+\text{sin. }^{-1}{\cdot}52)+2{\cdot}75.$$

But the arc whose sine is $0{\cdot}52=31°\ 20'$

$$\therefore d=1{\cdot}1\sqrt{18{\cdot}24}+5\text{ sin. }(120°+31°\ 20')+2{\cdot}75$$

$$=4{\cdot}697+5\text{ sin. }28°\ 40'+2{\cdot}75$$

since sin. $(180-x)=\sin x$.

$$\therefore d=4{\cdot}697+5\times0{\cdot}47971+2{\cdot}75=9{\cdot}85''$$

But $v=p+d=r_1-c+d=5-2{\cdot}4+9{\cdot}85=12{\cdot}45''$

and $b=4d-\frac{2r}{r_1}\sqrt{r_1^2-(c+l)^2}=39{\cdot}40-9''{\cdot}394=30''{\cdot}016.$

The length of the screws on the stem ss must therefore be d+length of the nut.

Much of the arithmetical work above, might have been omitted,

but it is thought the method will be more readily comprehended by giving *all* the details of the computation.

The small valves are therefore efficient between the limits $x=0$ and $x=120°$, and the engine may be stopped by means of the expansion gear. By contracting these limits the ports may be made smaller. For instance, if it is not required to cut off the steam below $\frac{1}{4}$th the stroke from commencement, *i. e.* to expand the steam more than through three-fourths the stroke, the value of *v may be diminished by the value d has for* $x=60°$. *b* will be diminished by *twice* the value *d* has for $x=60°$.

The above dimensions are by no means meant for a criterion, since the *assumptions* must vary with the case and judgment of the designer; but are simply used as an illustration—although correct for the assumed conditions.

Naval Academy, Newport, R. I., Jan. 25, 1864.

An Account of some Researches on Radiant Heat. By JOHN TYNDALL, Esq., F.R.S., Prof. Nat. Phil., Royal Inst.

In his former researches on the radiation and absorption of heat by gaseous matter, the speaker compared different gases and vapors at a common thickness with each other; one part of his present object was to compare different thicknesses of the same gaseous body with each other as to their action upon radiant heat. A few years ago he would be deemed a bold man who would attempt to measure the action of an inch, or indeed of many feet of a gas, on radiant heat; but the present experiments commence with plates of gas only 0·01 of an inch in thickness, and extend to thicknesses of 49·4 inches. Thus, the greatest thickness is to the least nearly in the ratio of 1 to 5000. The apparatus employed for the smaller thicknesses was a hollow cylinder, one end of which was closed by a plate of rock-salt. Into this fitted a second cylinder, with its end also closed by a plate of the salt. One cylinder moved within the other like a piston, and by this means the two plates of salt could be brought into flat contact with each other, or could be separated to any required distance. The distance between the plates was measured by a *vernier*. The cylinder was placed horizontal, being suitably connected with a source of heat. This latter consisted of a plate of copper, against which a steady sheet of flame was caused to play.

The absorption of radiant heat by carbonic oxide, carbonic acid, nitrous oxide, and olefiant gas was determined with this apparatus, and such differences as might be anticipated from former researches were found. Olefiant gas maintained its great superiority over the other gases at all thicknesses. A layer of this gas, not more than 0·01 of an inch in thickness, intercepted about 1 per cent. of the total radiation; and the delicacy of the apparatus may be inferred from the fact that this absorption—great, relative to the thickness of the layer of gas, but small absolutely—corresponded to a deflection of 11 degrees of the galvanometer. (It would be certainly possible to measure the

action of a layer of this gas of less thickness than the paper on which these words are printed.) A layer of olefiant gas, 2 inches in thickness, intercepts nearly 30 per cent. of the entire radiation. The influence of a diathermic envelope surrounding a planet may be strikingly illustrated by reference to this gas. A shell of olefiant gas, 2 inches thick, surrounding the earth, would offer no appreciable hindrance to the solar rays in their earthward course; but it would intercept, and in great part return, 30 per cent. of the terrestrial radiation; under such a canopy the surface of the earth would probably be raised to a stifling temperature. A layer of the gas, $\frac{2}{10}$ of an inch thick, intercepts 11·5 per cent. of the whole radiation. Such a layer, if diffused through a stratum of air 10 feet thick, would be far more attenuated than the aqueous vapor actually diffused through the air; still it would produce an absorption greater than that which the speaker had assigned to the atmospheric vapor within 10 feet of the earth's surface. In the presence of such facts, the arguments which we might be disposed to base on the smallness of the quantity of atmospheric vapor are entirely devoid of weight.

In measuring the action of larger thicknesses of gas, the following method was pursued:—A brass cylinder, 49·4 inches in length, had its two ends stopped with plates of rock-salt, and a suitable source of heat placed at one end; the rays from this source passed through the tube, and were received by a thermo-electric pile placed at its opposite end; this radiation was exactly neutralized by the heat emitted from a cube of boiling water and incident on the opposite face of the pile. The interception of any portion of the heat emanating from the source by a gas or vapor introduced into the tube destroyed the equilibrium previously existing, and the amount intercepted was declared by the galvanometer. The thickness traversed by the calorific rays was varied in the following way:—The tube was divided into two distinct compartments by the introduction of a third plate of rock-salt. Let us agree to call the compartment most distant from the pile the *first chamber*, and that adjacent to the pile the *second chamber*. The experiments began with the first chamber short and the second chamber long, and ended with the first chamber long and the second chamber short. The alteration consisted solely in the shifting of the intermediate plate of salt, which lengthened the first chamber and diminished the second one by the same quantity; the sum of the lengths of both chambers being the constant quantity, 49·4 inches.

The absorption effected in the first chamber acting alone was first determined; then the absorption effected in the second chamber acting alone; and, finally, the absorption effected when both the chambers were occupied by the gas or vapor. This arrangement enabled the speaker to check his experiments, and also to examine the effect of the *shifting* which occurred in the first chamber on the absorption of the second one. The thermal coloration of the various gases was rendered strikingly manifest by these experiments. For the vast majority of the rays, for example, carbonic oxide and carbonic acid are transparent. Placing a stratum of carbonic oxide, 8 inches in length, in front

of a column of the same gas, 41·4 inches long, these 8 inches intercepted 6 per cent. of the whole radiation; placed *behind* a column 41·4 inches long, the absorption of the same 8 inches was sensibly *nil*. So also with carbonic acid; 8 inches in front absorbed 6¼ per cent., while placed behind the effect was almost zero. Similar remarks apply to the other gases, the reason manifestly being that when the 8-inch stratum is in front, it stops the main portion of the rays which give it its thermal color, while, when it is placed behind, these same rays have been almost wholly withdrawn, and to the remaining 94 per cent., or thereabouts, of the radiation the gases are sensibly transparent.

An extension of this reasoning enables us at once to conclude, that the sum of the absorption of the two chambers taken separately must always be greater than the absorption effected by a single column of the gas of a length equal to the sum of the two chambers. This conclusion is illustrated in a striking manner by the experiments; and it is further found that when the mean of the sums of the absorption is divided by the absorption of the sum, the quotient is sensibly the same for all gases. It may also be inferred from considerations similar to the foregoing, that the sum of the absorptions must diminish, and approximate to the absorption of the sum, as the two chambers become more unequal in length, and that the sum of the absorptions of the two chambers is a maximum, when the medial rock-salt plate divides the long tube into two equal compartments.

In these days a special interest attaches itself to the radiation of any gas through itself or through any other gas having the same period of vibration. The speaker referred to the results of an elaborate series of experiments on this interesting question. The experimental tube, 49·4 inches long, was divided into two compartments by a partition of rock-salt. All external sources of heat were abolished, and the pile, furnished with its conical reflector, stood at the end of the tube. The compartment nearest the pile contained the gas which was to act as absorber, while that most distant from the pile held the gas which was to act as radiator. It is known that the destruction of the motion of a sensible mass of matter is always accompanied by the evolution of heat. A weight falling to the earth, and a ball striking a target, are heated on collision. The same is true for atoms, and in the present experiment the gas in the radiating chamber was heated by the collision of its own particles against the inner surface of the tube when they rushed in to fill the vacuum. The radiation was, in fact, what the speaker had named "dynamic radiation." The lengths of the two chambers were varied, the radiating column being lengthened and the absorbing one shortened at one and the same time; the sum of both was always the constant length 49·4 inches.

The experiments with the vapors were thus executed. Both the chambers into which the tube was divided were, in the first place, occupied by the vapor to be examined; the usual pressure being $\frac{1}{30}$ of an atmosphere. The entrance of the vapor was so slow, and its quantity so small, that the radiation due to the warming of the vapor by its own collision was insensible. The needle being at zero, dry air was

allowed to enter the chamber most distant from the pile. This air became heated dynamically, communicated its heat to the vapor, and the latter immediately discharged the heat thus communicated to it against the pile. It is quite evident, that not only does this case resemble, but that it is actually of the same mechanical character as that in which a vibrating tuning-fork is brought into contact with a surface of some extent. The fork, which before was inaudible, becomes at once a copious source of sound. What the sounding-board is to the fork, the compound molecule is to the elementary atom. The tuning-fork vibrating alone is in the condition of the atom radiating alone, the sound of the one and the heat of the other being alike insensible. But in association with sulphuric or acetic ether-vapor the elementary atom is in the condition of the tuning-fork applied to its sound-board, communicating through the molecule motion to the luminiferous ether, as the fork through the board communicates its motion to the air.

The experiments demonstrate the great opacity of a gas to radiations from the same gas. They also show in a very striking manner the influence of attenuation in the case of vapor. The individual molecules of a vapor may be powerful absorbers and radiators, but in thin strata they constitute an open sieve through which a large quantity of radiant heat may pass. In such thin strata, therefore, the vapors, as used in our experiments, were generally found far less energetic than the gases, while in thick strata the same vapors showed an energy greatly superior to the same gases. The gases, it will be remembered, were always employed at a pressure of one atmosphere.

A few striking experiments were referred to in illustration of the influence of a paper lining, or a coat of varnish or lampblack, within the experimental tube. In dynamic radiation it is not possible to do entirely away with the action of the interior surface of the tube itself. When the tube is of brass and well polished within, the entrance of the air produces a deflection of 7·5 degs., this being due to the emission from the warmed surface of the tube. A lining of paper two feet long raises the radiation sufficiently to drive the needle through an arc of 80 degrees, while a ring of paper $1\frac{1}{2}$ inches long placed within the tube radiates sufficient to urge the needle through an arc of 56 degrees.

The speaker finally examined the diathermancy of the liquids from which his vapors were derived, and the result leaves no shadow of a doubt upon the mind, that both absorption and radiation are molecular phenomena, irrespective of the state of aggregation. If any vapor is a strong absorber and radiator, the liquid whence it comes is also a strong absorber and radiator. The molecule carries its power, or want of power, through all its states of aggregation. The order of absorption in liquids and vapors is precisely the same; and the speaker looked forward with hope to the application of these results to other portions of the domain of thermotics.

Proceedings Royal Institution, June 12, 1863.

Boiler Explosion on the Great Western Railway.

From the London Practical Mechanic's Journal, Feb., 1864.

The inquiry into the cause of the recent explosion on the Great Western Railway took place, 20th November, 1863, near the scene of the occurrence. It will be remembered that Dr. Lankester adjourned the inquests on the deaths of the three men who were killed by the bursting of the engine, in order that he might have scientific evidence in respect of the state of the boiler both before and after the explosion, and also on the subject of the management of locomotives generally. Captain Tyler, R. E., Government Inspector of Railways, attended, and assisted in examining the other witnesses. The officer also submitted himself for examination, and read a detailed report which he had drawn up after an inspection of the remains of the Perseus. John Thompson, the driver of the Perseus, stated that on the morning of the day before that on which the accident took place he drove the engine from Swindon to London. In the course of that journey he drove it with a pressure of 115 lbs. on the square inch, and he observed nothing wrong with its boiler. He made a note in the engine-drivers' book of some slight repairs that had to be done with other parts of the Perseus, and the boiler was washed out. The Perseus had been running 12 years, but there were hundreds of older engines on the Great Western line. Mr. L. Young, boiler maker in the company's workshop at Swindon, stated that the last occasion on which the interior of the boiler of the Perseus was thoroughly examined was in 1855, when new pipes were put into it. Since then repairs had been done to the boiler on one or two occasions; but he had seen nothing to make him think that there was corrosion in the place where it subsequently gave way. When there was a suspicion of weakness in any part of a boiler, small holes were tapped and a gauge was introduced to try the thickness of the metal; but if there was no such suspicion no regular examination of the boiler took place except when new pipes were being put in. The pipes put into the Perseus in 1855 were in it when it exploded, and in the interim the engine had run 175,000 miles. The duration of pipes was usually measured by the number of miles which the engine had run, and they usually lasted for a mileage of from 100,000 to 200,000 miles. Mr. Daniel Gooch, chief engineer of the locomotive department, was the next witness. He stated that, including both broad and narrow gauges, there were about 500 engines in the rolling stock of the Great Western Company. The Perseus was a first-class broad-gauged engine, and was not an old one as compared with others belonging to the company. It was 12 years old, while there were more than 200 which were much older. Some had been running 24 or 25 years without new boilers. The Perseus had never had new boilers. It was the duty of each engine-driver after every journey to make a written report of anything that his locomotive required to have done to it, and the engine was not let out again until the necessary repairs were completed. The Perseus had 303 pipes. If the pipes of an engine were taken out they could not be put in again. New ones must be supplied,

and they cost from 25s. to 27s. each. In reply to Captain Tyler, Mr. Gooch said that he did not approve testing boilers for strength of plates by the hydraulic process. This test was applied when the engine was at rest, and the strain to which the boiler was subjected, and which was much greater than any that it was ever required to bear when running, was calculated to injure it. He was persuaded that if the hydraulic test was applied they would have many more explosions. None of the great companies applied it. The engineers of the London and North-Western, the Great Northern, and the South-Western were against it. Captain Tyler observed that the hydraulic test was applied by the engineers of some lines, and with very beneficial results. Some locomotives had given away under it. Mr. Gooch further stated that he had several boilers of greater age than that of the Perseus tested, and he found them all sound. As to pipes, there was one engine on the line which had run 280,716 miles with the same set of pipes. Mr. Gooch, as well as the engine-driver and boiler maker, attributed the bursting of the boiler to corrosion of a part of one of the plates in the centre of the boiler barrel. Captain Tyler concurred with the officers of the company as to the immediate cause of the accident, but thought that the hydraulic test might have been applied with great advantage, and expressed his opinion that the running of an engine for seven years without a thorough examination of the interior of the boiler was a most dangerous proceeding. He observed, however, that there was no Government regulation on this point, and that there was considerable difference of opinion as to the merits of the hydraulic test. He brought under the notice of the Court and the officials of the Great Western Company a boiler manufactured by a firm at Ipswich, in which the pipes were so placed that they could be removed in a mass and replaced again. This invention had not as yet been applied to railway locomotives, but was confined to agricultural engines. It was not, however, clear to him that it might not be made available for railway engines. The jury found that the death of John Elridge, James Wilson, and Christopher Thomson (the men killed by the explosion), was accidental; but they recommended to railway companies a periodical examination of the boilers of their locomotives at intervals not exceeding three years.

Here we have exactly the case of the Rugby explosion over again, and the same dogmatic absurdity on the part of the locomotive engineering evidence—absurdity, if not something worse, that scarcely needs dissection. Ah! these tubes, that cost 27s. a piece, and would so probably blow out often in the hydraulic test—*hinc illæ lacrymæ*. What a comfortable assurance to Great Western travelers is that of Mr. Gooch! The engine that exploded was 12 years in use, and *had never been thoroughly examined for eight years;* but that is nothing, the Company have 200 engines a great deal older, and in worse condition! —Ed.

Tides of the White Sea.

From the London Athenæum, Jan., 1864.

The question as to the existence of a diurnal periodicity in the tides of the White Sea may now be considered as decided in the affirmative; for we find in the last number of the *Bulletin* of the Imperial Academy of Sciences of St. Petersburg a short notice of a report presented by Messrs. Lenz and Kupffer, in which the fact is stated for the first time. M. Zaroubine, an officer of the Corps of Pilots at Archangel, has made a long series of observations, and drawn up tables of the results, which have been laid before the Academy, and discussed by the reporters, who affirm his conclusion that a diurnal periodicity in the flux and reflux of the tides in the White Sea is thereby demonstrated. The report and a selection of the tables are to be published; but, we fear, in Russian only, and in a Russian periodical.

Talmi Gold.

From the London Chemical News, No. 213.

A beautiful gold-colored alloy, sold under the above name, gave, on analysis, the following results:—

Copper . . .	86·4
Zinc . . .	12·2
Tin . . .	1·1
Iron . . .	0·3

The iron was probably an accidental ingredient. The alloy besides was very thinly gilt. It is a good deal used to make watch-chains.

Centralblatt, No. 52, 1863.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, February 18, 1864.

William Sellers, President, in the chair.

John H. Towne, Vice President.

Robert Briggs, Corresponding Secretary.

Washington Jones, Recording Secretary.

The minutes of the last meeting were read and approved.

A letter was read from the Smithsonian Institution, Washington, D. C.

Donations to the Library were received from the Royal Astronomical Society, the Royal Institution, the Statistical Society, and the Commissioners of Patents, London; la Société Industrielle de Mulhouse, France; Prof. A. Dallas Bache, the Smithsonian Institution, and Thos. U. Walter, Esq., Washington, D. C.; Hon. Mr. Brady, Senate, Harrisburg, Pa.; the Pennsylvania Institution for the Blind, Prof. John F. Frazer, and John S. Cassin, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's report for January was read.

The Board of Managers and Standing Committees reported their minutes.

The Board of Managers reported the appointment of the following Standing Committees of the Board.

On Publications.	*On Instruction.*	*Managers of Sinking Fund and Finance.*
John H. Towne,	John F. Frazer,	George Erety,
Fairman Rogers,	Pliny E. Chase,	Washington Jones,
Robert Briggs,	J. Vaughan Merrick,	John F. Frazer,
B. Henry Bartol,	Coleman Sellers,	Percival Roberts,
George Harding.	Samuel Sloan.	Samuel White.

Candidates for membership in the Institute (6) were proposed, and the candidates proposed at the last meeting (15) were duly elected.

On motion, a committee of five were appointed to revise the By-Laws, and report, if in their judgment they needed amendments.

Committee, Messrs. J. Vaughan Merrick, Washington Jones, Bloomfield H. Moore, Pliny E. Chase, John H. Towne.

On motion, a committee of twelve were appointed to consider the weights and measures, and coinage of the United States, with regard to the proposed introduction of the decimal system.

Committee, Messrs. Robert Briggs, Fairman Rogers, J. Vaughan Merrick, John F. Frazer, John H. Towne, B. Henry Bartol, John W. Nystrom, Washington Jones, Coleman Sellers, James C. Booth, William B. Bement, Samuel J. Reeves.

The Standing Committees for the ensuing year were appointed by the President, and approved as follows:—

On the Library.	*On Cabinet of Minerals and Geological Specimens.*	*On Cabinet of Models.*
Henry Ames,	Robert Briggs,	James Agnew,
Pliny E. Chase,	Isaac H. Conrad,	William B. Bement,
James H. Cresson,	John F. Frazer,	Charles H. Cramp,
James Dougherty,	J. Peter Lesley,	Mordecai W. Haines,
John Ferguson,	Samuel J. Reeves,	John Kile,
George Harding,	Robert E. Rogers,	W. Barnet Le Van,
Raper Hoskins.	B. Howard Rand,	Charles T. Parry,
James T. Lukens,	Coleman Sellers,	John L. Perkins,
Henry G. Morris,	Richard Tilghman,	Samuel Sloan,
William H. Merrick.	Elias Wildman.	S. Lloyd Wiegand.

On Cabinet of Arts and Manufactures.	*On Exhibitions.*	*On Meetings.*
William Adamson,	Robert Briggs,	B. Henry Bartol,
John H. Cooper,	James H. Cresson,	Charles S. Close,
Charles G. Crane,	John Gardiner, Jr.,	Henry Cartwright,
William Divine,	Edwin Greble,	George Erety,
Henry R. Lawrence,	Bloomfield H. Moore,	Henry Howson,
Percival Roberts,	J. Vaughan Merrick,	Edward Longstreth,
Newbold H. Trotter,	William A. Mitchell,	John W. Nystrom,
Eliashib Tracy,	T. Morris Perot,	Percival Roberts,
Samuel S. White,	John H. Towne,	Thomas Shaw,
William Weightman.	O. Howard Wilson.	Montgom'y P. Simons.

Charles M. Cresson,	Henry Morton,
John F. Frazer,	James A. Meigs,
Henry Hartshorne,	Fairman Rogers,
James Hunter,	James S. Whitney,
James A. Kirkpatrick,	Samuel S. White.

Mr. Chase continued the abstract of his papers on Tides of Rotation.

The principal theories that have been brought forward to account for the barometric tides, attribute them to

1. Variations of temperature,
2. Variations of moisture,
3. Formation and dissipation of clouds,
4. Electrical action of the sun,
5. Gravitation,
6. Centrifugal force,
7. "Rotation of the earth, and its connexion with the solar system."

[*W. C. Redfield*, in Silliman's Journal, vol. xxv, page 129.]

No one has attempted to point out any minute or precise correspondence between theory and observation, nor to furnish any satisfactory demonstration of the connexion between the observed phenomena and their supposed causes.

The prevailing sentiment of the day appears to incline towards the temperature theory, notwithstanding the confessedly inexplicable difficulties that attend it. James Hudson, (London Phil. Trans., 1832) points out "the general relation between the barometrical changes and the variations of temperature," but he admits that the relation "appears to be DIRECT during the morning hours, and INVERSE during those of the day and evening." Sir John Herschel says that "heat causes diurnal variations, but the effects surpass the natural operation of those causes." Prof. Espy, (4th Meteorolog. Rep. p. 12,) attempts to reconcile the American observations with his view of the heat theory: his explanations, though plausible, are unsatisfactory and will not bear the test of rigid scrutiny.

Each of the other enumerated causes undoubtedly exerts an influence which must be carefully investigated, before we can obtain a thorough knowledge of the laws which control the atmosphere. Such an investigation will probably show a mutual connexion through which all the secondary causes may be referred to a single force. Mr. Redfield's hypothesis, which is expressed in terms sufficiently indefinite and general to include all the rest, was anticipated by Galileo, who attributed the ocean tides "to the rotation of the earth, combined with its revolution about the sun." It appears that Galileo's opinion attracted little attention, and led to no special investigation, partly, perhaps, because it could hardly be reconciled with the tidal intervals, and partly because a literal, as well as figurative, reasoning in a circle, apparently demonstrated that the motions in question could produce no disturbing force. I have endeavored to show the fallacy of this notion, and to justify my reasoning by exhibiting the almost precise coincidence between the results of my hypothesis, and those of observation. My views are still further confirmed by the fact that the law of tidal variation de-

rived from an exclusive reference of the aerial motions to a supposed stationary earth, is precisely the same as the law that is derived from the consideration of the relative attractions of two bodies revolving about their common centre of gravity.

The following table furnishes material for many instructive comparisons, some of which deserve special notice on account of the additional confirmations that they furnish to the rotation theory. The column headed "observed height of barometer," gives the grand mean of three years observations at St. Helena; A represents the theoretical height as computed by our formula; B introduces such modifications as would result from assuming the mean of the equatorial observations as a normal equatorial altitude.

TABLE OF MEAN BAROMETRICAL RESULTS, THEORETICAL AND OBSERVED.

Time.	Ratio of Observed Heights.	Observed Height of Bar. 28 in +	Theoret. Height A 28 in. +	Error A.	Theoret. Height B 28 in.	Error. B	Diff. of Errors.
0 h	1·00060	·2985	·2970	—15	·3002	17	—32
1	1·00000	·2819	·2821	2	·2821	2	0
2	·99945	·2660	·2672	12	·2640	—20	32
3	·99905	·2553	·2563	10	·2507	—46	56
4	·99894	·2521	·2523	2	·2458	—63	65
5	·99908	·2562	·2563	1	·2507	—55	56
6	·99938	·2642	·2672	30	·2640	— 2	32
7	·99982	·2764	·2821	57	·2821	57	0
8	1·00028	.2899	·2970	71	·3002	103	—32
9	1·00065	·3003	·3079	76	·3135	132	—56
10	1 00086	·3061	·3119	58	·3184	123	—65
11	1·00074	·3025	·3079	54	·3135	110	—56
12	1·00033	·2913	2970	57	·3002	89	—32
13	·99988	·2777	·2821	44	·2821	44	0
14	·99938	·2646	·2672	26	·2640	— 6	32
15	·99908	·2562	·2563	1	·2507	—55	56
16	·99905	·2550	·2523	—27	·2458	—92	65
17	·99926	·2611	·2563	—48	·2507	—104	56
18	·99973	·2737	·2672	—65	·2640	—97	32
19	1·00028	·2898	·2821	—77	·2821	—77	0
20	1·00081	·3048	·2970	—78	·3002	—46	—32
21	1·00120	·3163	·3079	—84	·3135	—28	—56
22	1·00130	·3184	·3119	—65	·3184	0	—65
23	1·00107	·3117	·3079	—38	·3135	18	—56

It will be seen that the purely theoretical height A corresponds more nearly with the observations than the mixed height B. It is therefore evident that there is a slight disturbance, (which may perhaps be owing either to variations of temperature, or to a resisting medium,) which follows a different law from the principal disturbance.

The changes are least near the times of high and low tide, and greatest midway between the two tides. If we compare the average high and low tides, we see that the observed height is somewhat less at high tide, and somewhat greater at low tide, than theory would give. These results would naturally follow from the combined fluidity and gravitation of the air.

From 1h. to 15h. inclusive (during most of which time the radius vector of each particle of air is increasing,) the observed height of the barometer is less than the theoretical height.

From 16h. to 0h. inclusive, (radius vector diminishing,) the observed height is greater than the theoretical height.

The greater pressure before noon than before midnight, is precisely the result which would follow from the passage of the earth through a resisting medium, but it is directly opposed to the supposed tendencies of varying temperature.

The apparent difference in the laws that govern the aerial and ocean tides may be partially, if not wholly, accounted for by considering the difference of constitution in the two media, and the relative positions of the observer. The air is highly elastic and compressible, while water is cohesive and incompressible; the observer is placed underneath the atmosphere, but above the ocean. The air can therefore readily yield to any expanding or condensing force, without much perceptible motion, while a similar force applied to water would produce motion in the direction of least resistance; any force that tends to throw fluids away from any given portion of the earth, produces a high aerial tide, but a low barometric tide, and after some interval a high oceanic tide.

The frequent coincidence of high water with a low barometer, has been noticed by many observers, and it is strikingly presented in the comparative drawings given by Lubbock in his Theory of the Tides. The prompt effect of rotation, combined with the retardation of the cumulative action which produces the lunar tides, may perhaps account for the errors of theory in Lubbock's Table of the

SEMI-MENSTRUAL INEQUALITY AT LONDON.

Apparent Solar Time of Moon's Transit B.	Height.		
	Theory.	Observation.	Error.
h. m.	feet.	feet.	feet.
0 30	22·72	22·72	0
1 30	22·54	22·44	+·10
2 30	22·07	21·92	+·15
3 30	21·36	21·14	+·22
4 30	20·55	20·23	+.32
5 30	19·83	19·57	+·26
6 30	19·56	19·55	+·01
7 30	19·93	20·26	—·33
8 30	20·69	21·15	—·46
9 30	21·49	21·89	—·40
10 30	22·16	22·42	—·26
11 30	22·59	22·70	—·11

The regular recurrence of the aerial tides at stated hours, is a sufficient evidence of their dependence upon the relative positions of the earth and sun. Though the differential effect of the moon's attraction

is greater than that of the sun's, the intensity of the solar attraction is much the greater. I am inclined to believe that this intensity is manifested in a greater stability of the solar attraction-spheroid, which prevents its yielding readily to the effects of rotation.

Lubbock quotes from Williams' Narrative of Missionary Enterprises, p. 172, his remarks on the "well-known fact that the tides in Tahiti and the Society Islands are uniform throughout the year, both as to the time of the ebb and flow, and the height of the rise and fall; it being high water invariably at noon and midnight, and low water at six in the morning and evening. The total range from low to high water seldom exceeds eighteen inches or two feet." The earth's rotation, producing an alternate half-day's acceleration and retardation in the eastward motion of the water, should create a tendency to tides of this character, and the situation of the islands mentioned is peculiarly favorable for the development of that tendency. Were they near a continent or at the entrance of a gradually narrowing ocean, they would feel the influence of the derivative tide which accumulates the attractive energies of the moon for several successive transits, and the tides would vary with the moon, as upon our own shores: but the nearly uninterrupted ocean sweep of 80° to the eastward may give the combined rotation and solar waves such resistless force, that they can easily overcome the weak intensity of the lunar attraction. If this hypothesis is confirmed by more accurate observations, the theory of Galileo will not only help us in our explanations of the aerial tides but it will also lead to the recognition of a most important element in the ocean tides.

Messrs. Cornelius & Baker exhibited a very beautiful method of *lighting gas* by means of frictional *electricity*, arranged for use with a bracket, two portable lighters, and a table light, all being simple in arrangement and readily kept in order.

These instruments are constructed upon the principle of the electrophorus.

The electric *bracket* is arranged with a brass cup in the form of a vase, resting upon the bracket, with a connecting piece of hard rubber. This cup is lined with lamb skin covered with silk, and contains the hard rubber electric piece which corresponds in form to the inside of the cup. A coiled covered wire connects the brass cup, with a wire attached to the burner, and terminating just above the burner.

In order to light the gas, the stop is turned, the hard rubber piece lifted partly from the cup, thus liberating the spark and lighting the gas.

The *Portable Lighter* consists of the same vase or cup, with the addition of a non-conducting handle.

When the brass cup is lifted from the electric piece and held to the conducting wire of the burner, the gas is immediately lighted.

Another portable instrument called *Double Air-Tight Electrophorus*, consists of two metallic tubes, each closed at one end, and connected together at the other, with a non-conducting ring of hard rubber, the inside being lined with lamb skin. A hard rubber rod is placed within them, the length of one of the tubes, and fitting them so as to move somewhat freely from end to end.

When the movable piece inside is allowed to fall to one end, and the tube is raised to the connecting wire of the burner, this piece changes its place again, falling into the tube held by the hand. The spark leaves the upper end of the tube at the same time and lights the gas.

The *Table Light Burner* consists of the same instrument arranged upon a pivot regularly attached to the pillar light.

Prof. J. C. Cresson exhibited some specimens of Lawrence's Metallic Paint, which he had used with very satisfactory results, both as a coating upon metals, and for making water-tight joints, and laid upon the table the following communication respecting it:—

Vivianite.—This mineral occurs sometimes with iron and copper pyrites, in which state it is found at St. Agnes, Cornwall, England. A very fine variety occurs in the gold mines at Vöröpatuck, near Siebenburg, Transylvania. It has also been found in Bavaria, in the Isle of France, and Brazil.

In this country, in two states only, has it been discovered. Mineralogists give it as a recent formation from animal matter, and their opinions are based on a variety discovered at Ballagh in the Isle of Man, accompanied by animal matter, particularly the bones of the elk and deer. At Edinburgh large quantities have been found under some old slaughter houses at the foot of the Castle Rock. In Europe it has long been used as a pigment, and preferred on both wood and metal, where the object is to protect the material from rust, rot and dampness, hence it is used largely on ships bottoms and hulls, iron railings, fences, roofs, brick walls, steam and water pipes, smoke stacks, &c., and as a paint there is none for the above named purposes to equal it.

The metallic base of the manufactured article (paint), is a combination of the peroxide and protoxide of iron with a small percentage of the peroxide of manganese.

R. Wood's cast iron Building Blocks were also exhibited. They consist of hollow shells of cast iron, having projections and holes arranged so that they may be connected together by inserting the projections of one block in the openings of the adjacent one.

By filling the shells with mortar they may be more firmly bound together; the mortar being poured into the upper row of shells, from which it flows readily to those below, through openings made for the purpose.

Mr. Thomas Shaw exhibited some samples of Homogeneous Cast Steel, made by Charles Cammell & Co. One of the specimens was a section of tube that was first flattened, and afterwards doubled over (cold), exhibiting a ductility superior to copper.

Mr. S. stated that he had seen tubes of the same metal that were pressed endwise into small cakes (not unlike collapsing a hat), without fracturing the metal.

The various uses to which this metal is applicable is obvious.

The following table of experiments made at Derby, England, January 4th and 5th, 1859, shows the comparative strength of the above metal:

EXPERIMENTS UPON HOMOGENEOUS CAST STEEL, IN COMPARISON WITH THE BEST IRONS.

No. of Experiment.	DESCRIPTION OF METAL.	SECTION. Length.	Width.	Thickness.	Area.	ELONGATION. 3	4	4½	5	5½	6	6½	7	7½	Percentage of Elongation.	Breaking Weight in Tons.	Breaking Weight per sq. in.	Strength compared with No. 1.	SECTIONAL FRACTURE. Length	Width	Area.
1	Homogeneous Steel, No. 3,	5¾			·234										8· 6	8	34·13	1			·141
2	Ditto,	"	"	"	"										29·09	8	34·13	1			·094
3	Homogeneous Steel, No. 2,	"	"	"	"										17·74	7½	32· 0	·9376			·117
4	Ditto,	"	"	"	"										21·74	7½	32· 0	·9376			·109
5	Homogeneous Steel, No. 1,	"	"	"	"										35· 0	6½	27·73	·8125			·082
6	Ditto,	"	"	"	"										21·74	6	25· 6	·7530			·125
7	Low Moor Iron,	"	"	"	"										23· 9	6	25· 6	·7630			·141
8	Ditto,	"	"	"	"										17·74	6	25· 6	·7530			·160
9	Northampton Iron,	"	"	"	"										17·74	5½	23· 5	·6885			·175
10	Ditto,	"	"	"	"										21·74	5½	23· 5	·6885			
11	Ditto,	"	"	"	"										19·56	5½	23· 5	·6885			
12	Jarrow Ship Plate Iron,	4½	"		·195										0· 7	4½	23· 8	·6750			·128
13	Ditto,	"	"	"	"										0· 0	4½	23· 8	·6750			
14	Staffordshire Iron, "Page's,"	5¾	"		·234										4·34	5	21· 3	·6240			
15	Ditto,	"	"	"	"										3·26	4½	19· 2	·5624			
16	Ditto,	"	"	"	"										4·34	4½	19· 2	·5626			

No. 3 hardens well.
No. 2 hardens, but not through.
No. 1 will not harden.

} These numbers do not indicate any difference in *quality*, but merely in the temper.

H. E. Thayer's improved Insulator for Telegraph Wires was exhibited. The body of the insulator is composed of a block of glass, protected by a bell-shaped casing of cast iron, through an opening in the top of which the glass projects; the casing being strongly cemented to the glass. To that portion of the glass projecting from the top of the casing is cemented a metal cap, from which projects three prongs, so arranged that the wire must be slightly bent in passing between them, it being thus prevented from slipping. The insulator is secured in its place by a pin which projects from the pole into an opening in the underside of the glass. Both the cap and casing are thus so completely insulated that there can be no communication between the wire and the pole.

The following communication from Mr. Thomas Shaw, was read, viz:

I desire to report a set of experiments by Dr. Howell, of New York, (who was appointed by the Cooper Institute) and myself, on Temperatures and Pressures; which experiments resulted in showing an error of 12½ per cent. in Regnault's scale, (the most reliable of the several scales published.) The apparatus we employed was a plain column of mercury, 40 feet high, (in order to give the pressure accurately, allowing 2·04 inches to the lb.) and a plain vertical boiler, three feet long, six inches in diameter; the heads welded on, capable of standing a pressure of 300 lbs. per square inch. The said boiler was heated at its lower end, with gas, in order to have no superheating at the top of the boiler where the thermometer was placed. The bulb of the thermometer was arranged to be immersed in the steam. There was a pipe communicating with the bottom of the boiler and the mercury column. The apparatus was operated in this wise: The boiler was filled half full of water, when the gas was ignited, heating the water and converting it into steam. The steam coming in immediate contact with the bulb of the thermometer, gave the temperature of the same, and by virtue of the pressure of the steam, forcing the water out of the pipe communicating with the mercury column, said column was elevated, thus giving the pressure. Different thermometers were used, and by three successive experiments we were forced to come to the conclusion that there was an error of 12½ per cent. in the above scale, *i. e.* one hundred lbs. by mercury column is 112½ lbs. Regnault's scale.

Several members replied to the above. They did not consider the experiments a sufficient data on which to pronounce Regnault's results to be erroneous.

A Comparison of some of the Meteorological Phenomena of FEB., 1864, *with those of* FEB., 1863, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	February, 1864.	February, 1863.	February, for 13 years.
Thermometer—Highest—degree, .	57·00°	54·00°	70·00°
" " date, .	28th.	10th.	23d, 1860.
" Warmest day—Mean,	49·67	46·00	59·30
" " " date,	28th.	27th.	25th, 1857.
" Lowest—degree, .	4·00	5·00	—1·00
" " date, .	17th.	5th.	7, '55; 8, '61.
" Coldest day—Mean,	7·00	11·17	5·70
" " " date, .	17th.	4th.	7th, 1855.
" Mean daily oscillation,	15·29	13·57	13·56
" " " range, .	7·18	7·54	7·30
" Means at 7 A. M., .	30·55	30·46	29·35
" " 2 P. M., .	40·57	37·70	38·55
" " 9 P. M., .	34·74	34·04	33·53
" " for the month,	35·29	37·07	33·81
Barometer—Highest—Inches, .	30·375 in.	30·671 in.	30·671 in.
" " date, . .	19th.	4th.	4th, 1863.
" Greatest mean daily press.	30·267	30·537	30·595
" " date, . .	18th.	4th.	12th, 1857.
" Lowest—Inches, .	29·284	29·345	29·065
" " date, . .	16th.	20th.	23d, 1853.
" Least mean daily press.,	29·383	29·501	29·227
" " date, . .	16th.	20th.	16th, 1856.
" Mean daily range, .	0·182	0·265	0·221
" Means at 7 A. M., .	29·792	30·031	29·919
" " 2 P. M., .	29·742	29·977	29·871
" " 9 P. M., .	29·796	30·024	29·904
" " for the month, .	29·777	30·011	29·898
Force of Vapor—Greatest—Inches,	0·262 in.	0·322 in.	0·549 in.
" " " date, .	1st.	6th.	16th, 1857.
" " Least—Inches, .	·022	·027	·013
" " " date, .	17th.	4th.	6th, 1855.
" " Means at 7 A. M.,	·132	·142	·139
" " " 2 P. M.,	·124	·149	·159
" " " 9 P. M.,	·139	·146	·157
" " " for the month,	·132	·146	·152
Relative Humidity—Greatest—per ct.,	90 per ct.	100 per ct.	100 per ct.
" " " date,	6th.	19th.	Often.
" " Least—per ct.,	20·0	29·0	20·0
" " " date, .	22d.	16th.	22d, 1864.
" " Means at 7 A.M.,	70·1	77·3	78·7
" " " 2 P.M.,	46·6	63·5	63·2
" " " 9 P.M.,	63·8	70·9	75·3
" " "for the month	60·2	70·5	72·4
Clouds—Number of clear days,* .	10	7	8·1
" " cloudy days, .	19	21	20
" Means of sky cov'd at 7 A.M.,	50·7 per ct.	73·6 per ct.	61·6 per ct.
" " " " 2 P.M.,	63·1	62·9	61·0
" " " " 9 P.M.,	47·6	63·9	47·2
" " " for the month,	53·8	66·8	56·6
Rain and melted Snow—Amount, .	0·697 in.	3·824 in.	2·730 in.
No. of days on which Rain or Snow fell,	5	13	10
Prevailing Winds—Times in 1000,	s80°41′ w·379	n56°19′w·139	n72°59′w·283

* Less than one-third covered at the hours of observation.